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Parent–infant synchrony and the construction of shared timing; physiological precursors, developmental outcomes, and risk conditions

Ruth Feldman
Bar-Ilan University, Israel

Synchrony, a construct used across multiple fields to denote the temporal relationship between events, is applied to the study of parent–infant interactions and suggested as a model for intersubjectivity. Three types of timed relationships between the parent and child's affective behavior are assessed: concurrent, sequential, and organized in an ongoing patterned format, and the development of each is charted across the first year. Viewed as a formative experience for the maturation of the social brain, synchrony impacts the development of self-regulation, symbol use, and empathy across childhood and adolescence. Different patterns of synchrony with mother, father, and the family and across cultures describe relationship-specific modes of coordination. The capacity to engage in temporally-matched interactions is based on physiological mechanisms, in particular oscillator systems, such as the biological clock and cardiac pacemaker, and attachment-related hormones, such as oxytocin. Specific patterns of synchrony are described in a range of child-, parent- and context-related risk conditions, pointing to its ecological relevance and usefulness for the study of developmental psychopathology. A perspective that underscores the organization of discrete relational behaviors into emergent patterns and considers time a central parameter of emotion and communication systems may be useful to the study of interpersonal intimacy and its potential for personal transformation across the life-span. **Keywords:** Parent–child relationship, parent–child interaction, regulation, prematurity, vagal tone, maternal depression, maternal anxiety, empathy.

> O chestnut-tree, great-rooted blossomer,
> Are you the leaf, the blossom or the bole?
> O body swayed to music, O brightening glance,
> How can we know the dancer from the dance?
> *E.B. Yeats*

Synchrony, 'the relation that exists when things occur at the same time' (Merriam-Webster Medical Dictionary, 2002), refers to a timed relationship, whether concurrent, sequential, or organized in an ongoing patterned format, between two or more events that cohere into a single process. As an area of scientific inquiry, the construct of synchrony has been applied to a range of phenomena, from the micro-level of cells, neurons, and genes (Blenkinsop & Lang, 2006; Klemm & Bornholdt, 2005) to the macro level of population growth and weather change (di Paolo, 2001) and the mental realm of the archetype (Jung, 1961). Interaction synchrony in the context of parent–infant relatedness, the focus of this review, addresses the matching of behavior, affective states, and biological rhythms between parent and child that together form a single relational unit. Synchrony describes the intricate 'dance' that occurs during short, intense, playful interactions; builds on familiarity with the partner's behavioral repertoire and interaction rhythms; and depicts the underlying temporal structure of highly aroused moments of interpersonal exchange that are clearly separated from the stream of daily life (Beebe, 1982; Fogel, 1993; Stern, 1977; Tronick, 1989; Trevarthen, 1979). Synchrony, therefore, provides one window to the nature of early relationships that is different from the angle captured by more global constructs such as sensitivity or responsiveness and highlights a distinct component in the attachment theory's focus on predictable caregiving as a critical feature of early infant care (Bowlby, 1969). Just as the laws of thermodynamics demonstrate that heat increases the speed of physiological processes, the high level of positive arousal that infants co-construct with their parents during the short daily episodes of face-to-face play, a level reached only during such shared moments, accelerates the maturation of the infant's relational skills and provides essential environmental inputs for the development of self-regulation and social fittedness (Feldman, 2003). The intensity of these moments, in turn, requires the external regulatory framework afforded by the organizational parameters of synchrony.

The temporal aspect, the defining feature of the synchrony construct, is equally central to its application to the parent–infant interaction research. The temporal parameters of the interactive flow, the rhythmic repetitions, the ongoing match of affective states, the sequential mirroring of the infant's communicative signals, and the parent's transformation

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of the infant's social bids into a variety of sensory modalities that preserve the intensity, shape, and rhythms of the original message mark the essence of the synchrony experience (Beebe & Lachmann, 1988; Brazelton, Koslowski, & Main, 1974; Papousek, 1996; Stern, 1974, 1999; Trevarthen, 1993). In its focus on the temporal and organizational features of the dyadic system, rather than on specific behaviors, synchrony describes a time-bound, co-regulatory lived experience within attachment relationships that provides the foundation for the child's later capacity for intimacy, symbol use, empathy, and the ability to read the intentions of others. Furthermore, synchrony as a time-based construct resonates with philosophical positions suggesting that human existence is defined by the experience of time and is relational in essence. This tradition is expressed in Bergson's (1907) 'duree', which highlights the present moment as a special (perhaps only) mode of being, in Husserl's (1977) intentionality that reveals the inherently relational nature of perception, action, and mental products, and in Levinas' (1987) formulations on the face-to-face position as affording the only opportunity for a meaningful contact with Otherness (Alteriety), which allows for an authentic encounter with another person. Synchrony as a conceptual framework also accords with biological perspectives postulating that living systems can be understood only in reference to their evolvement in time (Edelman, 1989), with dynamic systems' models that consider time an indispensable parameter of emerging systems (van Geert, 1994), and with neurobiological perspectives that underscore the inseparateness of the self from biological processes that maintain basic life functions, in particular, oscillators that modulate the rhythms of breathing, sleep, and hormone release (Damasio, 1999). Such rhythms ground the self in the regularity of bodily processes, as suggested long ago by Freud. With time, the maturing brain maps these physiological periodicities into an ongoing sense of self that can remember the past and project to the future. As will be demonstrated below, interaction synchrony provides infants the only opportunity to match their own biological rhythms with those of another human being, co-creating not only a shared relational moment but a shared biology. By taking part in a matched interpersonal dialogue, the unfolding experience of shared timing – the dance – becomes inseparable from the evolving person – the dancer.

This review addresses the topic of parent–infant synchrony in the first year of life, spanning the period from the emergence of biological rhythms in the fetus during the third trimester of pregnancy (Mirmiran & Lunshof, 1996; Pillai, James, & Parker, 1992) to the first appearance of symbols in the parent–infant play toward the end of the first year (Tamis-LeMonda & Bornstein, 1994). Only studies that empirically test the temporal relationship between the ongoing behaviors of parent and child and apply one of three functional definitions to its measurement are included: a) synchrony as a 'match' or 'co-occurrence' between the behaviors or affective states of parent and child; b) synchrony as the sequential relations between the behavior of one partner and the following behavior of the other; and c) synchrony as the ongoing lagged associations between the parent's and infant's stream of behaviors as measured by time-series analysis. These measures tap the three prototypes of synchrony as a timed relationship between two events; concurrent, sequential, and organized in an ongoing patterned format. Although studies may apply various terms, such as co-regulation (Fogel, 1993), mutual influence (Cohn & Tronick, 1988), mutual regulation (Gianino & Tronick, 1986), affect attunement (Stern, 1985), contingency (Nichols, Gergely, & Fonagy, 2001), or coordination (Jaffe, Beebe, Feldstein, Crown, & Jasnow, 2001), they all investigate the unfolding of social behavior in time and the associations between events that seem to be meaningfully connected. Outcomes of the parent–infant synchrony in the areas of cognitive, symbolic, social-emotional, self-regulatory, and moral development will be addressed and potential mechanisms by which synchrony facilitates development in these domains proposed. The role of biological rhythms in providing the foundation for parent–infant synchrony will be discussed and data are presented to show the entrainment of biological rhythms during synchronous interactions. The coordination of social behavior in the family context is presented as the basis for the infant's experience within the cultural context. Finally, risk conditions related to mother or child that may compromise the expression of synchrony will be addressed and specific interactive profiles for each pathological condition are detailed.

Figure 1 describes the developmental sequence of synchrony from the third trimester of pregnancy to the end of the first year.

As seen, the first period to be considered in the time-line of synchrony is the last trimester of pregnancy, due to the role of biological rhythms, emerging at this stage, in providing the neurobiological substrate for coordinated interactions (Feldman, 2006). At birth, the infant's innate tendency for contingency detection (Tarabulsy, Tessier, & Kappas, 1996) and the mother's natural adaptation of the species-specific set of maternal behavior to the infant's cues (Fleming, O'Day, & Kraemer, 1999) mark the human infant's first experience in a temporally-matched interaction. Synchrony in its more conventional form, as the ongoing patterned coordination of discrete interactive behaviors in various modalities, is typically observed during the third month of life, and over the next six months, until infants reach the age of intersubjectivity at around 9 months, social interactions mature in various ways and develop into a true give-and-take mutuality

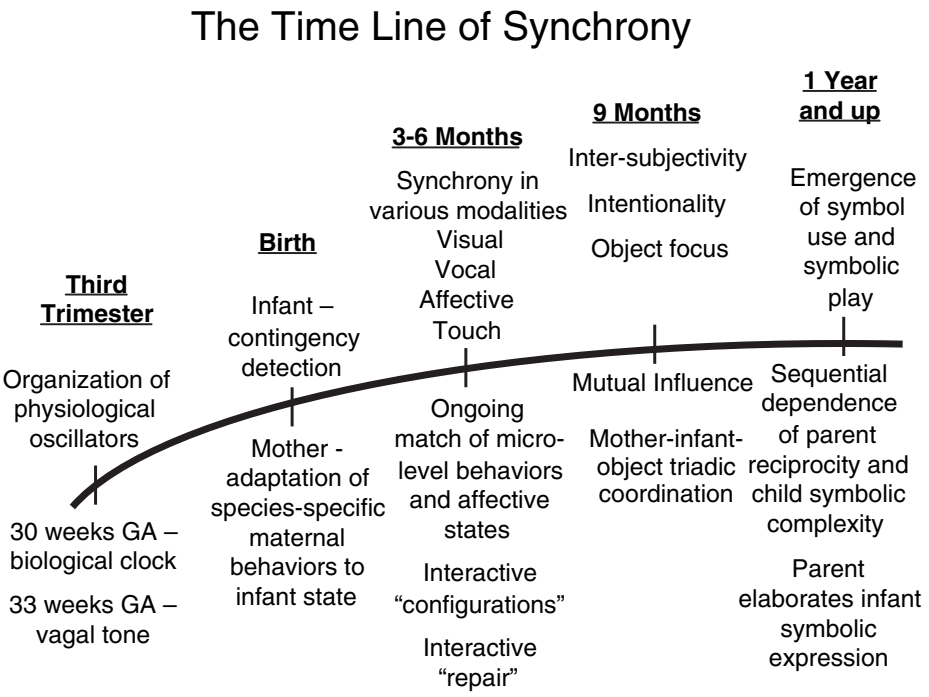

Figure 1 The time-line of synchrony across the first year

(Stern, 1985). Toward the end of the first year, as infants begin to use symbols in word and gesture (Bates, O'Connell, & Shore, 1987), the synchrony experience undergoes further transformation that opens the previously established non-verbal reciprocity to the entire range of creative symbols the individual may use throughout life while maintaining the basic sequential dependence between the behaviors of self and other.

I. Synchrony as co-regulation; from external regulation to mutual regulation

A. External regulation

Authors on synchrony concur that one of its core functions lies in facilitating infant self-regulation by means of a co-regulatory process (Feldman, 2003; Field, 1994; Fogel, 1993; Tronick, 1989). Regulation is perhaps the most widely used construct in current developmental research that still awaits a comprehensive definition. In essence, regulation refers to the organization of discrete components into a unified system (Tucker, Luu, & Pribram, 1995), the cycling of that system between processes of excitation and inhibition (Posner & Rothbart, 2000), and the integration of physiological, behavioral, and mental processes into a goal-directed action which is then internalized as mental representation (Fox & Calkins, 2003). Because of the human infant's extreme immaturity at birth, infants depend on the caregiving context for relatively long periods and require specific environmental inputs for the regulation of biological and behavioral systems (McKenna & Mosko, 1994). The most important source for the provision of such inputs is the mother's body and physical presence, and the maternal proximity and interactive behavior serve an 'external regulatory' function for the organization of neurobiological, sensory, perceptual, emotional, physical, and relational systems (Hofer, 1995; Hrdy, 1999). Development is thus grounded in relationships and this initial dependence of the infant on the mother's body opens the lifelong neurobiological possibility that one person can serve an 'external regulatory' function to the physiological systems of another through timely adaptation to distress and social cues (Feldman, 2004; Hofer, 1996). Indeed, studies on maternal deprivation have long shown that maternal absence in humans and mammals is associated not only with physiological dysregulation but with social withdrawal, apathy, and disengagement (Harlow, 1958; Spitz, 1946). The mother's arms, the provision of touch and contact, is the place where the infant's discrete sensory experiences and internal states begin to consolidate into a rudimentary sense of self (Gottlieb, 1976; Sander, 1984) and where relationships evolve from a less specific external regulatory function to specific, individually-matched attachments (Bowlby, 1958; Winnicott, 1956). The mother's holding environment is also the place where synchrony begins; biologically, behaviorally, and interpersonally. Rhythmic patterns of neonate activity, such as crying, nursing, or sucking, serve as the earliest means of communication (Wolff, 1967; Burke, 1977; Crook, 1979), and mothers model interaction rhythms on such patterns, for instance, the 'burst–pause' pattern typical of early face-to-face play (Tronick, Als, & Brazelton, 1977). During the first two months of life touch gives way to gaze as the

central mode of interpersonal relatedness and gaze synchrony becomes the main vehicle for social interactions throughout life (Wright, 1991). Paradoxically, then, synchrony emerges at the point when separation between mother and child begins. From an evolutionary perspective, the transition from touch to vision reflects a shift from maternal behaviors shared by all mammals to relational behaviors that are exclusively human and draw on patterns of mutual gazing and the matching of facial expressions. This human mode of relatedness, in turn, predicts the exclusively human aspects of infant development – symbol formation, empathy, and the development of moral internalization (Feldman & Greenbaum, 1997; Feldman, 2005).

Maternal postpartum behavior: The infant's first experience in social contingencies. The behavioral building blocks of synchrony: vocalizations, facial expressions, affective display, proximity position, body tone and movements, and affectionate touch – relational patterns observed across all cultural communities in different mixtures (LeVine, 2002; Richter, 1995) – have their origin in the set of maternal postpartum behaviors during the bonding stage. Fleming and colleagues (1999) suggest that bonding involves species-specific sequences of maternal behaviors that are coordinated with specific infant neurobehavioral sensitivities to maternal cues, including voice, touch, body rhythms, and odor. Over time, autonomic, neurological, and endocrinological systems in each partner are sensitized to the temporal patterns of the other, leading to the formation of a unique bond. Although the maternal postpartum behavior is genetically programmed, it is highly open to environmental influences and cultural meaning systems (Carter & Keverne, 2002; Keller, 2003; Leckman et al., 2004). The postpartum maternal repertoire in humans includes gaze at the infant's face, 'motherese' high-pitched vocalizations, affectionate touch – a behavior akin to the 'licking-and-grooming' of mammals that shapes the pup's life-long stress reactivity and the cross-generation transmission of parenting (Champagne & Meaney, 2001) – and careful adaptation to the infant's state and signals (Barratt, Roach, & Leavitt, 1992; Cohen & Beckwith, 1979; Feldman & Eidelman, 2003; Feldman, Eidelman, Sirota, & Weller, 2002; Fleming, Steiner, & Corter, 1997; Miller & Holditch-Davis, 1992; Minde, Perrotta, & Marton, 1985). Mothers naturally 'synchronize' these behaviors with the neonate's scant moment of alertness. In a recent study, mothers and neonates were observed in a 15-minute free interaction and maternal and infant behaviors were micro-coded. Infants spent about 15–20% of the interaction in alert-scanning state and conditional probabilities showed that mothers engaged in maternal behavior for approximately 65% of that time but provided little social stimulation otherwise (Feldman & Eidelman, in press). By coordinating social behavior with the infant state, mothers capitalize on the neonate's innate capacity to detect contingencies between discrete events in the environment, between different modalities in the infant's own behavior, and between the behaviors of self and other (Tarabulsy et al., 1996). Such inborn contingency detection was first described by Condon and Sander (1974), who showed that neonates move their limbs in coordination with the adult's speech, and contingent sequences between infant body movements and adult behavior are observed even among very low birthweight preterm infants (Eckerman, Oehler, Hannan, & Molitor, 1995). Interestingly, contingent reactivity in neonates has been described only in face-to-face paradigms, suggesting that the temporal patterning of social interactions may be triggered at the very first moment that biological dispositions (i.e., face preference) are integrated with critical environmental inputs (a real human face).

Several studies examined physiological precursors and developmental outcomes of the mother's postpartum behavior. Maternal behavior is supported by hormonal systems that undergo change during pregnancy and sensitize mothers to infant cues, such as oxytocin and prolactin (Grattan et al., 2001). Oxytocin, a neuropeptide released during uterine contraction and milk ejection, has been implicated in the initiation of maternal behavior in mammals and in close bonds across life (Insel & Young, 2001; Kosfeld et al., 2005). In a recent study, pregnant women were observed at three time points; first trimester, third trimester, and first postpartum month. Plasma oxytocin was assayed at each stage, mothers reported symptoms of anxiety and depression, and at the third assessment mothers were videotaped interacting with their newborns and interviewed regarding the bonding process. Oxytocin levels averaged across pregnancy and the postpartum predicted not only the frequency of maternal behavior but the degree of its coordination with the newborn's alert state, pointing to the role of oxytocin in setting the stage for bonding in humans as well as in the development of coordinated interactions (Feldman, Levine, Zagoory-Sharon, & Weller, 2006). Mothers who provided more coherent and emotionally rich narratives regarding their newborns and the maternal role were found to engage in more elaborate postpartum behaviors (Keren et al., 2003). Longitudinal studies indicated that the amount of maternal postpartum behavior predicted the infant's later neurobehavioral maturation (Feldman & Eidelman, 2003), cognitive growth (Cohen & Beckwith, 1979; Feldman, Eidelman, & Rotenberg, 2004), and attachment security (Goldberg, Perrotta, Minde, & Corter, 1986). Most importantly, the degree of coordination between maternal behavior and the newborn's alert state was related to both infant–mother and infant–father synchrony at 3 months (Feldman & Eidelman, in press), suggesting that the

mother's postpartum behavior plays a central role in sensitizing infants to the temporal dimension of social relationships. In charting the weekly development of mother–infant co-regulation from birth to 3 months, Lavelli and Fogel (2005) showed that in the first month of life coordinated interactions circled around simple attention of the infant to the mother's face. At around 2 months, a more complex behavioral pattern emerged, emotional expressions became coordinated with visual attention, and transitional probabilities revealed more complex sequential relationships between the partners' behaviors that involved infant cooing, gazing, and smiling. According to Trevarthen and Aitken (1999), these early expressions of social coordination in the neonatal period function as 'primary intersubjectivity', a preliminary phase of human relatedness that sets the stage for more reciprocal modes of interpersonal mutuality.

Sensitive periods. The conceptualization of synchrony as a regulatory process that plays a formative role in the organization of neurobiological systems suggests a 'sensitive period' perspective (Bornstein, 1989); infants who did not experience coordinated interactions with a significant other during the first weeks of life may suffer lifetime difficulties in their social, emotional, and self-regulatory growth. One useful biological model in the present context is the learning of a birdsong, a process that has been proposed as a model for social development in the human infant (Jarvis, 2004). The learning of a birdsong requires a finely-tuned interplay between specific brain structures, neurochemical systems, genetic and epigenetic influences, imitative learning, and error detection, all within a very narrow time-window, else the structural changes that enable the production of the song do not evolve (Margliash, 2002; Williams, 2004). Songbirds learn with remarkable precision the tonal, rhythmic, and structural characteristics of their species' song, similar to the human infant's impressive capacity to perceive the rhythmic and affective features of the mother's style. Just as the bird's fittedness to the pack depends on proper song-learning at specific moments in development, the child's capacity to function as a socialized adult, use symbols, express empathy, and resonate with the emotional states of others may depend on the early participation in a well-fitted, tightly-structured exchange with an attuned adult. This 'sensitive period' approach is central for the conceptualization of continuity from synchrony in the first months of life to the child's cognitive, social, emotional, and self-regulatory skills in childhood and adolescence.

B. Mutual regulation

The building blocks of synchrony: co-occurrence and sequential relations. Between the age of 2 and 3 months, parent–infant interactions begin to show a clear temporal structure, in terms of behavior matching, sequential relations, and time-series parameters. Interactions at this age involve repetitive-rhythmic cycles of behaviors in different modalities, including gaze, touch, affective expression, body orientation, manual actions, and arousal indicators. Specific combinations of interactive behaviors become more frequent and turn into repetitive, almost automatic 'configurations' (Weinberg & Tronick, 1996), constellations of behaviors, which, from a dynamic systems' perspective (Fogel & Thelen, 1987), are viewed as 'attractor states' – interpersonal patterns that appear frequently and are likely to shape neural pathways. For instance, different types of smiles tend to co-occur with different gaze directions and facial expressions (Messinger, Fogel, & Dickson, 1997); mothers' speech to the infant typically follows the child's non-distress vocalizations (Hsu & Fogel, 2003); mothers and infants typically match the level of affective engagement and arousal (Cohn & Tronick, 1987); and dyads tend to cycle between states of matched and mismatched affective states in a relatively predictable rate (Weinberg, Tronick, Cohn, & Olson, 1999). Similarly, social versus object focus at play tends to co-occur with the expression of discrete emotions, such as joy versus interest (Weinberg & Tronick, 1996).

Sequential relations between maternal and child behaviors often lead to rhythmic chains of interactive behaviors that are organized as a stochastic process (Gottman, 1981, see below). Mothers tend to 'frame' the infant's actions with social attention and positive affect. For instance, the mother's positive expression often precedes the infant's becoming positive, infant high arousal is often preceded by states of quiet alertness and neutral arousal, and mother vocalizations often frame the infant's babbling (Cohn & Elmore, 1988; Cohn & Tronick, 1987; Feldstein et al., 1993; Kaye & Fogel, 1980). Infants' manual actions form similar sequences in combination with specific facial, visual, and affective components. Finger pointing often occurs before mouthing, finger curling appears during vocalizations, and hand closing is associated with maternal 'still-face' refraining from communication (Fogel & Hannan, 1985; Legerstee, Corter, & Kienapple, 1990). In using such 'framing' methods, mothers augment the infant's attention by maintaining the balance between the familiar and the novel and setting the play stage as an important arena for cognitive growth. Messer (1994) suggests that the repetitive nature of early social play functions as a continuous habituation task; mothers maintain infants' attention to an optimal level for information intake and when attention declines, introduce novel stimuli, thereby facilitating cognitive development, mastery motivation, and information processing skills.

At the 3 months stage, the sharing of social gaze between parent and child becomes the central

modality of coordinated interactions, occurring between 30 to 50% of the time in low-risk samples (Harel et al., 2005; Fogel, 1977; Tronick, Als, & Brazelton, 1980; Messer & Vietze, 1984; Pawlby, 1977). A recent review of ERP studies in infancy showed that at 4 months only a stimulus involving the human face gazing directly at the infant, not a face gazing elsewhere, activated the 'social brain' circuitry, including the superior temporal sulcus, the fusiform gyrus, and the orbitofrontal cortex (Johnson et al., 2005), and parents may naturally accentuate moments of mutual gaze to activate the emerging social brain. Mutual gaze also provides the framework for coordinated behaviors in other modalities. For instance, at 3 months parents tend to touch their infants affectionately and infants begin to respond with touch that gradually grows into an intentional loving touch. Episodes of parent and infant's loving touch are often integrated into moments of gaze synchrony in both infant–mother and infant–father play (Feldman & Eidelman, 2004). Co-vocalizations, moments in which parent and child vocalize 'in unison', begin to appear at that age and often occur during episodes of shared gaze (Beebe & Gerstman, 1980). At 3–4 months of age infants are not yet able to grasp or manipulate objects and their only opportunity for active participation in the world is through the give-and-take of social exchange. This purely social period in infant development is suggested to provide important neurological preparedness for the child's lifelong involvement with objects and exploration of the environment (Rochat, 1999), grounding the brain's capacity to acquire meaningful knowledge in the reciprocity of human relationships.

It is important to note, however, that the aforementioned 'configurations' typical of face-to-face play are shaped by cultural norms, and different constellations of interactive behavior may be more or less salient in different cultures. Parents in Western societies tend to provide more gaze, vocalizations, and object presentation and 'package' these behaviors in specific coordinated sequences. Parents in African, Middle-Eastern, or Far-Eastern cultures, on the other hand, provide more bodily contact and interactions contain less gaze, voice, and object use or the synchronization of these behaviors into timed patterns (Feldman, Masalha, & Alony, 2006; Keller et al., 2004; Rothbaum et al., 2001). These differences in interactive behavior reflect underlying cultural philosophies on the nature of the self and its relation to the social world; as a separate, autonomous, goal-directed entity or as embedded within social relationships (Markus & Kitayama, 1991; Triandis, 1989). Possibly, interactions that are not based on gaze synchrony – a mode of relatedness between separate individuals – may offer external regulation, interpersonal timing, and the organization of social behavior in ways that are yet to be fully explored.

Between the ages of 3 and 9 months, several interactive configurations consolidate while others decrease in frequency. Cohn and Tronick (1987), assessing children at 3, 6, and 9 months, found that at 3 and 6 months maternal positive engagement preceded the infant becoming positive but such sequential links were not observed at 9 months, pointing to the growing independence of the infant's positive engagement from the mother's moment-by-moment support. Touch synchrony – the coordination of affectionate touch with episodes of shared gaze – increases significantly from 3 to 9 months with the development of infant fine-motor skills (Granat, 2005). The most pronounced change across this period is observed in the infant's growing interest in objects and the dyadic focus on toy manipulation. Between 3 and 9 months, episodes of shared gaze decrease to about a third of the time while shared attention to objects increases dramatically (Landry, 1995). Figure 2 presents data from our lab showing developmental change from 3 to 9 months in three domains: gaze synchrony, shared attention, and mutual synchrony in the lead–lag structure (see below). As seen, objects become the focus of the parent–infant play in the second half-year, highlighting the dynamic relationship between developments in the motor domain – which allow infants to crawl, grasp, and manipulate objects – and the development of social competencies.

Time-series analysis; the dance, interactive errors, and repair. Studies applying time-series analysis to the assessment of synchrony focus on the temporal parameters of the ongoing play. In this line of research, the stream of each partner's behavior is micro-analyzed and the lagged association between the two time-series is assessed after the periodicities in each partner's behavior are statistically removed, in an attempt to quantify parameters of the 'dance'. This approach is dynamic in nature, focuses on the

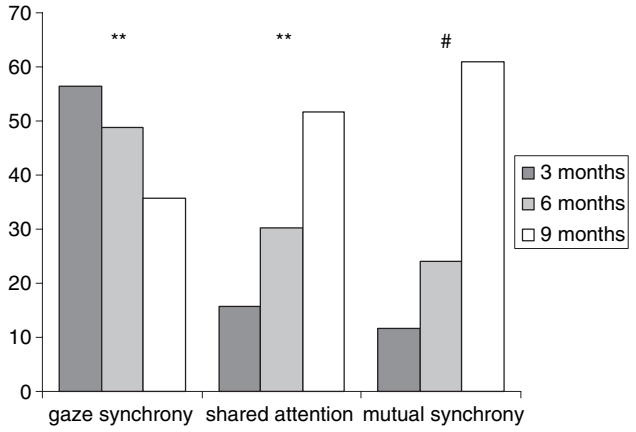

Figure 2 Proportions of gaze synchrony, shared attention, and mutual synchrony at 3, 6, and 9 months
$^{**}p < .01$. Numbers represent mean proportions at each age. $\#p < .01$. Numbers represent proportions of dyads with a mutual synchrony lead–lag structure out of the entire sample at each age

move from one state to the next rather than on the match of states, and enables the definition of synchrony as a match in the direction of change, not necessarily as a match of phase (Gottman & Ringland, 1981). An example of such synchrony occurs when the infant shifts from gaze aversion to social attention and the parent responds with a parallel shift from social attention to social stimulation and high positive arousal within lags of seconds (Cohn & Tronick, 1988; Field, Healy, Goldstein, & Guthertz, 1990; Lester, Hoffman, & Brazelton, 1985).

Three temporal parameters of synchrony have been described in studies utilizing time-series analysis. The first is 'coherence' or the degree of synchrony, a variable indexed by the largest cross-coefficient on the CCF plot (in the time domain) or the cross-coherence between the two amplitudes on the power spectra (in the frequency domain). This variable describes the 'degree of matching' between the partners' play by quantifying the lagged associations between the two time-series. The second parameter is the lead–lag structure, addressing the question of 'who is driving the interaction'; does the child lead the 'dance' and the parent follows, the parent lead and the child follows, or are the two partners mutually responsive to changes in each other's behavior? The third parameter is the time-lag to synchrony – the lag in seconds between change in one partner's behavior and parallel change in the other's. In low-risk samples at 3–4 months, the initial period of synchrony, the cross-correlations coefficient after partialing out the autocorrelated cycle in each partner's behavior is in the magnitude of $r = .20$; synchronous interactions are of the 'infant-lead-mother-follows' type, and the time lag to synchrony is between 1.5 and 2 seconds (Feldman, Greenbaum, Yirmiya, & Mayes, 1996; Feldman, Greenbaum, & Yirmiya, 1999). These parameters are highly sensitive to infant biological risk and to the caregiving context.

Between 3 and 9 months, the temporal parameters of synchrony undergo transformation. Although the level of coherence remains unchanged across this period, as infants enter the age of intersubjectivity at around 9 months (Stern, 1985) the lead–lag structure is altered and interactions are mainly of the mutual synchrony type where both partners are responsive to each other's rhythms (Figure 2). The time lag to synchrony decreases from 3 to 9 months, reflecting the familiarity with the partner's play and the growing specificity of the relationship, which facilitates a quicker match (Feldman, Greenbaum, & Yirmaya, 1999). The degree of synchrony (coherence) is individually stable across the first year and thus, although the lead-lag structure shifts from the parent's synchronizing with the infant state to mutual adaptation, dyads maintain the degree of coordination across time (Feldman, 2005). Finally, specific alterations in the temporal parameters of synchrony are associated with different pathological conditions originating in mother, child, or context.

In analyzing synchrony as the unfolding dance between matched and mismatched states, Tronick (1989); Tronick & Cohn, 1989) pointed out that mother and child spend most of their playtime in mismatched, rather than matched states, yet most of the mismatch is repaired in the next step. By highlighting the concepts of mismatch and repair, the theoretical focus shifts to the way dyads repair moments of miscoordination as the central component of intimate relationships and of the synchrony experience. A major function of the co-regulatory process, therefore, is the self-correcting capacities of the dyad and the infant's growing appreciation that relationships are not always fully attuned to one's needs. This conceptualization echoes psychoanalytic theories, such as Loewald's (1960) and Kohut's (1977) notions on internalization as based on maternal provisions that are removed in a gradual, well-timed manner, or Winnicott's (1971) formulations on creativity and symbol use as emerging from the mental space that opens between mother and child when the mother's physical presence must be replaced by a mental image.

Synchrony with mother, synchrony with father; two schema of 'being with other'. Very few studies compared the temporal parameters of synchrony in infant–mother and infant–father interactions. Dickson, Walker, and Fogel (1997) examined the co-occurrences of infant smile type and play type during interactions with each parent. Loglinear analysis indicated that during father–child interactions, object-oriented play was more frequent and tended to co-occur with basic smiles, whereas mother–child play included more vocalizations. We observed 100 first-time mothers and fathers interacting with their 5-month-old firstborn child (Feldman, 2003). Time-series analysis of each interaction, coded in 1-second frames, showed that during play with mother, infants cycled between states of low and medium arousal, often with one peak of high positive emotionality during the engagement episode. Mother–child play focused on face-to-face exchange and included patterns of mutual gazing, co-vocalization, and affectionate touch integrated into timed configurations. During play with fathers, the time-line of arousal contained several quick peaks of high positive emotionality, including joint laughter and open exuberance, and individual linear regressions showed that these peaks became more frequent as play proceeded. Father–child interactions centered on physical games or games with an object focus rather than on attention to micro-level face-to-face signals, findings consistent with previous research (Lamb, 1977; Yogman, 1981). However, despite the differences in 'content', no differences were detected in the temporal parameters, indicating that play with father may be as synchronous as play with mother.

Among the most interesting findings to emerge from the mother–father comparisons related to the gender-matching status of parent and child; father–son and mother–daughter dyads showed the highest levels of synchrony, in terms of higher coherence, more mutuality in the lead–lag structure, and shorter time-lags to synchrony. It has been suggested that synchrony builds on the infant's biological rhythms and extends it to social relatedness (Lester et al., 1985; Wolff, 1967). The female newborn's higher social orientations, observed in longer periods of eye contact and more smile and rhythmical mouthing, and the male newborn's frequent peaks of excitement, quicker rapidity of buildup, and higher reflex startling (Korner, 1969; Osofsky & O'Connell, 1977), may be more easily matched during an exchange that builds on these innate dispositions. Mothers and fathers, therefore, afford infants two modes of co-regulation. Interacting with mother and father, infants learn from the start that interpersonal intimacy may come in different forms; some relationships focus on micro-shifts in facial signals whereas others are directed to exploring of the outside world; some are moderate in intensity whereas others may be more arousing and exciting; some are consistent with the individual's biological tendencies while others may require some adjustment. These findings reflect Stern's (1995) notions on 'schema of being-with other', which postulate that early relational patterns construct person-specific internalized models that serve as the basis for intimate relationships throughout life (Cassidy & Shaver, 1999). In the same vein, Weinberg and colleagues (1999) showed that mother–son dyads took longer to repair from mismatched to match states, and this may be related to the gender mismatching status of mother and son. In addition, the data may provide further insight into the well-established link between early father absence and the development of externalizing problems and conduct disorders in boys (Cabrera et al., 2000). Since synchrony is central for the development of self-regulation, the lack of early coordination with the father, the natural form of synchrony for the young boy, is likely to disrupt the acquisition of self-regulatory skills.

Synchrony in the triad; the infant's entry into the cultural milieu. If dyadic synchrony is the playfield for intimacy, family interactions provide infants the first opportunity to participate in a group experience. During triadic sessions infants engage simultaneously in two separate relationships as well as observe the interaction between their parents, a task infinitely more complex than dyadic synchrony. The cultural mode of interpersonal relatedness, including the extent of physical contact, degree of permitted gaze with elders, and level of expressed positive affect – patterns that reflect cultural norms, values, and social hierarchies – become all the more salient during triadic play (Kagitcibasi, 1996). Naturalistic observations of the family indicated that the behaviors of mothers and fathers change when the other parent is present (Belsky, 1981), suggesting that family sessions may take a somewhat different form than dyadic moments and may have unique long-term effects on the infant's entry into the social world.

The notion that families function as unitary systems that are integrated from the relational behaviors of each family member has predominated in the field of family theory and research for over four decades (Bell, 1961; Epstein, Bishop, & Levine, 1978; Minuchin, 1974). In assessing synchrony in the triad, coordinated patterns in each family subsystem must be considered; the spousal, mothering, and fathering subsystems (Belsky, 1981; McHale & Cowan, 1996). Using a paradigm called the Lausanne Triadic Play, Fivaz-Depeursingue and Corboz-Warnery, (1999) applied micro-level coding to triadic interactions and showed that already at 3 months infants can synchronize their behavior with two social partners and can respond to subtle interactive signals between their parents. On the basis of specific behaviors in each subsystem, four types of family 'alliances' were described; the disordered, collusive, stressed, and cooperative, each depicting specific configurations of behaviors in the facial, vocal, and postural channels and defining a range from pathological to growth-promoting types of families.

We used a similar approach to study the organization of behavior in the triad and coded micro-level patterns of gaze, affect, touch, and proximity position in the three subsystems. In addition, during the infant's play with one parent, the behavior of the other was coded as disengaged, supportive, or intrusive and the shift in the infant's interactive focus was marked (Feldman, Weller, Eidelman, & Sirota, 2003). Overall, infants spent slightly more time interacting with mother than with father during triadic sessions. Interactions with mother contained more social gaze and co-vocalization whereas interactions with father were more oriented toward objects, indicating that the 'maternal' and 'paternal' modes of relatedness are retained in the family context. Mothers tended to be more supportive of the father–child exchange whereas fathers were more disengaged when mothers took the lead. Sequential analysis revealed that mutual gaze between the parents preceded an infant's partner shift, suggesting that infants notice the 'handing over' of the interaction between parents. It thus appears that already at 3 months infants are sensitive not only to shifts in the relational behaviors directed to them but also to micro-level signals in the interactions of others. Such attention to both the social partner and a third party probably precedes the person–person–object 'joint attention' abilities emerging around 9 months, which provides the basis for intentional action and theory of mind skills (Tomasello, Carpenter, Call, Behne, & Moll, 2005).

Cross-cultural assessments of family interactions have rarely been conducted. In a recent longitudinal study we examined triadic synchrony in the interactions of Israeli and Palestinian parents and their firstborn child (Feldman, Masalha, & Alony, 2006). As expected, the most notable cultural differences were related to the child's proximity position vis-à-vis the parents. Arab parents placed the infants on their lap or arms for approximately 83% of the time, a position that affords continuous contact but little social gaze, whereas Israeli infants were placed in a face-to-face position about 74% of the time. These basic postural differences resulted in culture-specific sets of social behaviors. Israeli parents, similar to parents in other Western societies, employed a distal relational style, involving mutual gaze, more shifts in affect (positive and negative), toy presentation, and active touch (Keller, 2003). Interactions among Arab families followed the proximal style; parents and child remained in close proximity, spouses maintained physical contact, affect was typically set at a neutral level, little shared gaze was observed, and the interactive flow was probably held by the contact between parents and child and among spouses. The coordination of gaze, affect, and touch into 'configurations' was also less common in the interactions of Arab parents and their infants.

Cultural modes of early relationships are likely to shape developmental outcomes in culture-specific ways, an assumption consistent with the 'cultural pathways' theory (Greenfield, Keller, Fuligni, & Maynard, 2003), which proposes that universal milestones are achieved in each culture in a different way. We found that the culture-specific modes of triadic synchrony predicted distinct modes of self-regulation in the preschool age. At 3 years, self-regulation was tested at childcare and observations focused on the child's ability to accept rules, regulate emotions, persist in activities, attend to new material, tolerate frustrations, postpone gratification, and adapt to transitions, capacities required for child participation in group activities in every culture. Comparable levels of self-regulation were observed in the two cultures. However, Israeli children scored higher on the 'Do' component of the self-regulation composite (Eisenberg, 2002), indicating their ability to mobilize action to the adult's requests, whereas Arab toddlers scored higher on the 'Don't' component, addressing their ability to refrain from action upon demand. Moreover, synchronous patterns of the triad differentially predicted self-regulation at the childcare setting. Israeli preschoolers receiving more social gaze and affectionate touch in infancy were more regulated at childcare, whereas Arab children whose parents provided more physical contact in infancy were more regulated as preschoolers. Micro-level patterns of synchrony, therefore, seem to contain important emotional, regulatory, and socio-cognitive information which is integrated with the cultural heritage, emerging brain circuits, and biological dispositions to form a unique relational experience, co-created at the present moment yet leaving a lasting mark on the infant's ultimate growth.

II. The time-line of synchrony; antecedents and outcomes

A. From biological rhythms to social rhythms

Since the first detailed assessments of the mother–infant exchange it has been noted that early interactions are organized in a repetitive-rhythmic structure (Beebe, 1982; Stern, 1974; Trevarthen, 1979; Tronick et al., 1977). The cyclic structure of face-to-face play was thought to reflect the infant's biological rhythms and synchrony was considered to express the dyadic adaptation to endogenous cycles of affective involvement (Lester et al., 1985; Wolff, 1967). During play, infants cycle between states of attention and non-attention and between episodes of positive and neutral affect in a pattern best described as a stochastic process (Cohn & Tronick. 1988). Stochastic processes address rhythmicity in probabilistic systems in which events can be reliably predicted from the immediately preceding events but the series as a whole does not follow a predetermined regularity (di Paolo, 2001; Gottman, 1981). As such, stochastic processes are more open to the changing behavior of the partner and to ongoing inputs from the external or internal environment (Fogel, 1977). Research of both adult–adult (Warner, 1992) and adult–infant (Feldman, Greenbaum, Mayes, & Erlich, 1997) interactions show that the autoregressive component in each partner's play (the tendency to cycle between states regardless of the partner's behavior) accounts for more variance than the cross-correlated function, indicating that internal rhythmicity is an important determinant of social interactions across life. Early communication systems, therefore, appear to develop through the ongoing integration of biological, emotional, and contextual components which provides a temporal framework for the organization of the infant's cognitive and affective experiences (Lerner, 1998).

In a recent study on the links between biological and social rhythms (Feldman, 2006), 71 infants were observed in three groups: extremely low birthweight infants born before the third trimester of pregnancy (<30 weeks gestational age), low birthweight infants born between 34 and 35 weeks, and full-term neonates. Sleep–wake cyclicity and heart rhythms in preterm infants were observed weekly until term age and full-term infants were tested on the second day. The emergence of the biological clock and sympathetic control over heart rhythms are dated to the last trimester of pregnancy, following structural and functional brain development, including the assembly of brain nuclei, rapid increase in synaptic growth, and maturation of neurochemical systems

(Levitt, 2003; Mirmiran & Lunshof, 1996; Peirano, Algarin, & Uauy, 2003). The weekly observations were conducted to detect the pattern of growth in each oscillator and the link between individual growth curves and the development of synchrony.

Consistent with the dynamic system's perspective on the emergence of novelty, which postulates that new forms of behavior emerge as a phase shift (Thelen & Smith, 1994), trend analyses showed that each oscillator had a developmental leap within a one-week time window followed by a period of consolidation. The phase shift for the sleep–wake cycle occurred between 30 and 31 weeks gestational age and the phase shift for cardiac vagal tone, an index of parasympathetic control over heart rhythms, followed between 33 and 34 weeks gestation. Infants with more mature biological rhythms at term age showed higher levels of mother–infant synchrony at 3 months. The degree of maturity in each biological rhythm was uniquely predictive of mother–infant synchrony, indicating that each oscillator marks a specific pathway to the emergence of synchrony. Moreover, among infants who showed immature cycles during the phase shift, no form of synchrony was observed. These data suggest a longitudinal, perhaps causal link between the consolidation of physiological periodicities in the third trimester of pregnancy and the emergence of social rhythms at the window for the development of social relatedness at 3 months.

Concurrent correlations between mother–infant synchrony and cardiac vagal tone were observed by Moore and Calkins (2004); infants who engaged in synchronous interactions with their mothers showed a greater vagal brake during the still-face that followed. The vagal brake measures change in vagal tone from a calm to stressed state and a greater brake indexes a more adaptive systemic adjustment to environmental intrusions. Porges (2003) theorizes that the emergence of behaviors and mental states related to affiliation, parenting, and intimacy is linked with the development of the polyvagal system across evolution. This development marks a shift from sympathetic-adrenal control of heart rate to the graded system observed in mammals that allows for quick changes in metabolic inputs and outputs from the heart and facilitates complex behaviors such as attention, orientation, and calm states required for bond formation. The removal of the vagal brake through signals from the vagus via myelinated pathways that originate in the nucleus ambiguus enables a rapid increase in heart rate in response to external or internal stresses and to better adaptation to changing environmental inputs, hence to more competent adaptation to micro-shifts in affective, facial, and postural cues, the abilities that underlie synchrony.

In a recent study, we (Moshe & Feldman, 2006) observed 3- and 6-month-old infants in mother–infant social interaction and still-face while both mother and child's heart rate was measured. Associations were found between maternal and child's vagal tone with indices of synchrony; gaze synchrony, co-vocalization, affectionate touch, and the 'framing' of infant positive affect in maternal positive engagement. In addition, taking Porges' formulations one step forward, we examined whether synchronous interactions would lead to the 'entrainment' of heart rhythms, the alignment of the two heart rhythms into a coordinated 'beat'. The two time-series of maternal and infant inter-beat-interval of heart rate (IBI) were plotted against each other in time. The time-series for each partner was measured as a differenced series of IBI change. Spectral density functions for each partner's time-series were computed with heart period series converted to point process (bin size = 1 ms) using a Hamming window (8, 192 bins). The coherence of mother and infant heart reate, smoothed within a 1 second epoch, showed that the largest coherence between the two time-series appears at around the frequency of 1.2 beats per second. Cross-correlation function (CCF) of changes in mother's and infant's heart rhythms was computed on the differenced time-series of change in the number of heartbeats per seconds. Similar to synchrony, this analysis considered the *rate of change* in heartbeat. Results of the CCF suggest synchrony in the acceleration or deceleration of heart rate within a lag of 3 seconds.

It is important to note that concordance in heart rhythms was not found in cases where little gaze synchrony was observed, a pattern typical of depressed mothers and their infants. Although preliminary and requiring replication and further analyses, these data provide the first evidence that the interpersonal match between mother and child may transcend the behavioral level to the biological level. This may suggest that within an attachment relationship, the individual's biological rhythms may be integrated into shared timing. Perhaps one reason for the strong impact of synchrony on the child's later development relates to the unique opportunity it affords for sharing one's basic life functions with a significant other.

B. Synchrony as providing the basis for symbol use, attachment, self-regulation, and empathy

Viewing synchrony from a 'sensitive period' perspective as a process that integrates biological rhythms and social signals into a highly intense event underscores its potentially formative impact on infant development. In charting developmental outcomes of synchrony, however, it is important to apply a multidimensional bioecological model (Belsky, 1984; Bronfenbrenner & Ceci, 1994), which considers the child's dispositions, the parent's personality and psychopathology, and the nature of the social context. More biologically regulated children elicit more reciprocal interactions from their care-

givers, but are also likely to develop self-regulatory and social-adaptive competencies. Mothers who attend to their infant's moment-by-moment communications are often less anxious, depressed, or self-indulgent and these qualities shape their entire parental approach. Similarly, certain environments are more or less conducive for optimal relationships. Continuity from infancy – the central theoretical issue of developmental research – must therefore be viewed from a multidimensional perspective that considers both specific experiences, such as synchrony, and macro-level factors that shape the person–context relationship.

Synchrony and symbolic competence. Among the important long-term effects of the synchrony experience is in sensitizing infants to the use of symbols. Several theoretical approaches suggest that the development of symbolic representations, emerging toward the end of the first year, is based upon the perceptual, motor, and affective experiences of the infant, in particular the ability to organize perceptions and actions into coherent structures (Bloom, 1970; Nelson, 1985; Piaget, 1962; Werner & Kaplan 1963). Others emphasize the social and affective contexts in which such early perception–action sequences are acquired and regard the ordering of discrete behavioral components into clear affective signals as precursors of symbolic thought (Fein, 1981; Mead, 1934; Stern, 1924). The acquisition of symbols, a specific domain of cognitive development, is thought to be particularly related to the mental acts of organizing, grouping, and ordering of repeatedly encountered perceptual, motor, and affective experiences (Thelen & Smith, 1994; Uzgiris & Hunt, 1987). Although developmental accounts on symbol formation vary, most theorists agree that symbols develop in relation to three conditions, two of which are clearly rooted in the parent–infant early affective matching. First, symbols emerge within an interactive context during positive moments between caregiver and child. Symbols are initially acquired through non-symbolic imitation games and these imitated schemes gradually assume symbolic meaning and grow independent of the social context. Second, symbols create coherences by reducing, grouping, and abstracting the shared characteristics of the represented phenomenon into a single concept while overlooking minor differences. Symbols develop on the basis of repetitive encounters with similar experiences and the ability to abstract order amid variability (Rogoff, 1990; Vygotsky, 1978). Finally, symbols imply the mental acts of substitution and referencing, capacities not yet fully available to infants. The ability to symbolically reference and intentionally communicate affective-behavioral patterns requires the further differentiation of self and other and the capacity to reflect on mental processes, capacities that appear toward the end of the first year (Fogel & Thelen, 1987; Tomasello et al., 2005).

In three samples we found associations between synchrony in the first year and symbolic play and theory of mind skills in later childhood. Synchrony with mother and with father, observed at 5 months, was related to the complexity of symbol use and to the sequences of symbolic play at 3 years in a relationship-specific manner. Symbolic play, like synchrony, is a process that evolves in time with distinct sequential relationships between the parent's affective expression and the degree of de-contextualization in the child's symbolic play (Slade, 1987; Damast, Tamis-LeMonda, & Bornstein, 1996). Mother–girl pairs who showed higher synchrony in infancy also displayed more complex symbolic play at 3 years and lag-sequential analysis detected more social-to-symbolic sequences in their interactions (sequences of shared gaze preceding episodes of complex symbolic play). For father–son pairs, higher levels of synchrony in infancy were related to more symbolic play at 3 years, but no sequential links were found between social play and symbolic complexity (Feldman, 2000). These data point to the centrality of the social component for the maternal style in interactions that call for moment-by-moment coordination. In a different sample, longitudinal relations were found between mother–infant synchrony at 3 and 9 months with symbolic play and internal state talk at 2 years (Feldman & Greenbaum, 1997). Internal state talk describes the child's use of words that refer to mental states, such as thoughts, feelings, or perceptions, and the attribution of these words to self or other. This type of talk emerges during the third year and is thought to set the stage for the appearance of theory of mind abilities in the fourth year (Bretherton, Fritz, Zahn-Waxler, & Ridgeway, 1986). The associations between synchrony and this line of development may suggest some form of preparedness to the mental and creative aspects of language and to the ability to see multiple perspectives. Finally, a group of 130 premature infants were followed from birth to 5 years. Synchrony with mother and father at 3 months predicted the child's functioning on theory of mind tasks at 5 years, in particular the understanding of emotions in others and the perception that the child's own emotions may be different from those of others, pointing to the role of synchrony in sensitizing infants to the understanding of emotions in self and other.

Synchrony and the capacity to self-regulate. Theories of social-emotional development emphasize the importance of early co-regulatory experiences for the development of self-regulatory capacities (Gianino & Tronick, 1986; Fogel, 1993; Schore, 1994). Kopp's model (1982) considers the antecedent of self-regulation from 3 months to 3 years, beginning with the mother–infant first coordinated interactions, enriched by the child's emerging motor skills and symbolic capacities, and

culminating at the stage of self-control at 2 years and self-regulation at 3 years, which imply the abilities to mobilize acts upon requests (Do) and inhibit actions upon demand (Don't). Guided by this model, we followed infants across childhood to examine the associations between early co-regulation and the ability to self-regulate. Synchrony was assessed with time-series analysis at 3 and 9 months and infants were followed at 2, 4, and 6 years in Do and Don't tasks. Recent research indicates that self-regulation, socialization, and moral internalization develop on the basis of the child's committed, self-regulated, and willing compliance to the parent's requests and prohibitions during the toddler and preschool years, as observed in Do and Don't contexts (Kochanska, 2002; Kochanska & Aksan, 1995). Self-regulated compliance, coded micro-analytically and averaged across 2, 4, and 6 years, was found to be predicted by the existence of mutual synchrony at 9 months, the lead–lag structure that marks the parent and child's mutual adaptation to shifts in the partner's affective state (Feldman et al., 1999). Infants who engaged in a mutual dialogue at the age of intersubjectivity were better able to self-regulate in the preschool years. In another study, synchrony with mother and with father at 3 months was related to fewer behavior problems at 2 years (Feldman & Eidelman, 2004), again pointing to the child's better abilities to self-regulate following the experience of synchrony. Consistent with Kopp's (1982) model, it appears that as the self is being assembled from the social world, mutual regulatory experiences play an important role in facilitating the child's abilities to self-regulate, obey social rules, engage in proper social conduct, and internalize a set of moral norms.

Synchrony and attachment security. Apart from the path provided by the shift from mutual to self-regulation, the link between synchrony and social adaptation may be mediated by its contribution to attachment security. Jaffe and colleagues (2001) found that vocal coordination between mother and infant at 4 months, assessed by time-series analysis and computed on the stream of vocalizations and pauses in each partner's behavior, predicted attachment security at one year. Interestingly, the data showed curvilinear associations between mother–infant coordination and attachment security; mid-range levels of synchrony were more conducive than a tightly-fitting match or an uncoordinated play in promoting attachment security. These findings emphasize that the experience of synchrony must leave room for unpredictability, mismatched states, and random events, and to contain both order and variability, stability and change, 'theme' and 'variations'. Isabella and Belsky (1991) similarly found links between synchrony at 1, 3, and 9 months and attachment security at one year. Although this study did not include time-based computations, some of the variables contained sequences of predictable caregiving, such as the mother's timely response to the infant's cry. Thus, as suggested by attachment theory (Bowlby, 1969), predictable caregiving may be a central contributor to attachment security on both the global level of childcare and the micro-level of moment-by-moment adaptation.

Synchrony and the capacity for empathy in adolescence. In the longest follow-up of parent–infant synchrony to date, infants were followed from 3 months to 13 years in order to assess the effects of synchrony on the adolescent's capacity for empathy and moral orientation (Feldman, 2005). Empathy was considered, in line with current views on morality and internalization (Eisenberg et al., 1996; Hoffman, 2000), as the core component in the child's moral orientation. At 6 and at 13 years, children's moral cognition was assessed through responses to moral dilemmas and the level of internalized norms, using Kohlberg's (1969) model. Dialogical empathy was assessed during two conflict discussions with the mother on a topic selected by mother and child to reflect common issues of conflict. Empathy was micro-coded in 10 second frames and considered the child's ability to see the perspective of the other, express empathy to others' distress, change mind in response to partner's comments, accept criticism, use a 'dialogical' mode of discourse, and provide a solution that considers the needs of others. The degree of synchrony across the first year was directly predictive of the level of empathy observed in adolescence. In addition, mediated links between synchrony and empathy were found through the child's self-regulatory abilities at 2, 4, and 6 years. These findings, viewed from a sensitive period perspective, suggest that participating in a synchronous exchange may afford a critical social experience that prepares infants to the emotional resonance and empathy underlying human relationships across the lifespan.

III. When synchrony fails: synchrony and developmental psychopathology

Synchrony is a feature of the dyadic system and thus may be compromised by risk conditions originating in both mother and child (Feldman, 2007). Prematurity as the child-related risk and maternal depression as the mother-related risk are the two conditions that received the most empirical attention to date. In our own work, parent–infant coordination has been tested in a range of infant-related risk conditions, including prematurity (Feldman, 2006; Feldman et al., 2003), multiple birth (Feldman & Eidelman, 2004), intrauterine growth retardation (Feldman, 2007; Feldman & Eidelman, 2006), feeding disorders (Feldman, Keren, Gross-Rozval, & Tyano, 2004a), clinic-referred infants with a variety of psychiatric conditions (Keren, Feldman, & Tyano,

2001), withdrawn infants (Dollberg, Feldman, Keren, & Gudueney, 2006), siblings of autistic children (Yirmiya et al., 2006), and young children suffering posttraumatic distress (Feldman, Hallaq, & Keren, 2006). In addition, synchrony was assessed among mothers with clinical depression and mothers suffering anxiety disorders (Feldman, Granat, & Gilboa-Schechtman, 2005). Data from these multiple studies indicate that mother–child coordination decreases in high-risk populations, regardless whether the risk is mother-related or child-related. Disruptions to the synchronous process were observed at all levels of coordination – the match of states, the co-occurrence of social behaviors, the sequences of ongoing play, and the temporal parameters of the synchronous 'dance'. Important, however, is to begin to chart specific interactive profiles that can be used to identify specific risk conditions. Such work may inform clinicians on issues of assessment, particularly as current theories in the field of infant mental health consider the mother–child relationship as a central component in the psychiatric evaluation of infants and young children (Feldman & Keren, 2004; Zero to Three, 1994). More specific tools to evaluate the dyadic relationship and insights from micro-level observations can be of much clinical use. Although often not possible in clinical settings, such information may direct clinicians' attention to specific behaviors that can be observed during an interview but would not have been noticed without prior research.

A. Infant biological risk and synchrony

Prematurity. The main cause for the disruption in parent–infant synchrony in cases of infant biological risk relates to the child's poor abilities to self-regulate physiological rhythms and attentional state (Minde, 2000). In general, interactions between premature infants and their mothers have been described as more intrusive and less coordinated in studies using both global rating scales and micro-level codes. Mothers often interfere with the infant's stream of behavior, tend to overstimulate the child, and are less able to adapt social behavior to the child's scant moments of attention. Micro-level assessments show that preterm infants are more irritable, their facial signals are less clear, and they are less able to tolerate shifts in affective behavior (Brachfeld, Goldberg, & Sloman, 1980; Eckerman, Hsu, Molitor, Leung, & Goldstein, 1999; Feldman et al., 2003; Greene, Fox, & Lewis, 1983; Lester et al., 1985). Similarly, premature infants are less able to organize responses in the gaze, affective, and motor modalities into coherent affective configurations (Malatesta, Culver, Tesman, & Shepard, 1989), which decreases the parent's capacity to read and respond to the infant's social cues. Because physiological rhythms in premature infants are dysregulated (Levitt, 2003), the biological basis for synchrony is compromised. The extent of mother–child mysynchrony was found to correlate with the level of infant medical risk at birth (Landry, Smith, Miller-Loncar, & Swank, 1998), indicating that the degree of CNS insult plays an important role in the development of mother–infant reciprocity.

Few studies assessed micro-level, time-based variables in mother–preterm interactions. In the neonatal period, mothers of premature infants provide less maternal behavior in the gaze, affect, and touch modalities (Cohen & Beckwith, 1979; Goldberg, 1978; Levy-Shiff, Sharir, & Mogilner, 1989; Miller & Holditch-Davis, 1992) and are less able to coordinate these behaviors with moments of infant alertness (Feldman & Eidelman, in press). As the mother's postpartum behavior provides the first practice in matched interactions, it is clear that preterm infants receive less than appropriate preparation for the development of synchrony. Lester and colleagues (1985) showed that the degree of coherence between the mother and infant's time-series of affective states and the cyclic structure of the infant's play was less organized, as measured by spectral analysis. A longitudinal study by Malatesta et al. (1989) followed preterm and full-term infants at 2.5, 5, 7.5, and 22 months. At each assessment, facial expressions of mother and child were coded in 1-second frames and contingency was defined as the mother's change of affective expression within 1 second of the infant's affective change. The authors found that in both stressful and unstressful situations, prematurity altered the course of infant affective expression and the maternal contingency levels, and these differences were observed well into the second year of life. Karger (1979) compared mother–infant synchrony between full-term and preterm infants at the neonatal period and at 1 and 3 months postpartum. Interactions were coded in 5-second frames, divided into twenty 18-frame episodes, and correlations between maternal and infant behaviors were computed for each frame and summed to form an index of synchrony. Lower levels of synchrony between maternal and infant behavior were found in the preterm group at 3 months. In a recent study on gaze behavior at our lab (Harel et al., 2005), interactions between mothers and their preterm and full-term infants at 3 months were micro-coded. Results showed that the frequencies of social gaze were higher for the preterm group; mothers and preterms engaged in frequent gazes, yet each gaze lasted only a few seconds.

Additional analyses were conducted to further understand the difficulties of the mother–infant dyad to maintain social gaze in the preterm group. The latency to the first episode of infant gaze aversion was 11 seconds in the preterm group, compared to 73 seconds for full-term infants, pointing to marked differences in the infant's ability to tolerate the highly arousing experience of gaze synchrony. Lag sequential analyses showed that preterm infants broke the

mutual gaze within 2 seconds of its initiation nearly four times as much as full-term infants. Importantly, however, a similar pattern was found for the mothers; mothers of preterm infants broke from mutual gaze within 2 seconds of the infant's social gaze seven times as much as mothers of full-term infants. The mother's augmentation of the child's attention to social and non-social stimuli provides an important foundation for the development of attention, cognition, and executive functions in infancy and childhood (Landry, 1995). The decrease in the dyadic capacity to augment periods of mutual gaze may be related, in part, to the difficulties observed in premature infants in the cognitive, attentive, and executive domains across childhood and beyond.

Intra-uterine growth retardation (IUGR). Infants with IUGR, particularly those born prematurely in addition to suffering retarded intrauterine growth, represent a subgroup of preterm infants that displays the highest levels of negative emotionality, physiological dysregulation, and difficulties in affective communication (Gorman, Lourie, & Choudhury, 2001; Mullen, Gracia-Coll, Vohr, Muriel, & Oh, 1988; Watt, 1986). Watt and Strongman (1985), observing IUGR, preterm, and full-term infants, found that the difference between IUGR and full-term infants was mainly related to a decrease in synchrony in the growth retarded group, computed as co-occurrences of matched affective states in mother and child's behavior. In assessing five groups of high-risk infants during mother–infant and father–infant interactions in comparison to controls, we found that the interactive profile of the IUGR group was the poorest of all groups. Such infants displayed the highest levels of negative engagement, their parents showed the most intrusive behavior, and the dyadic atmosphere was described as the least reciprocal during interactions with mother, father, and the triad (Feldman, 2007). In a different study, we followed IUGR infants from birth to 2 years in comparison with both birthweight-matched and gestational age-matched controls. Mother–infant interactions at 3 and 24 months in the IUGR group showed significantly higher levels of maternal intrusion and infant negative emotionality as compared to both control groups, and these patterns were especially high among IUGR infants born at extremely low birthweight (<1000 gr; Feldman & Eidelman, 2006). Although no time-related measures were coded in this study, the interactive aspects compromised by IUGR are related to the dyadic–systemic features of the interactions; reciprocity and intrusiveness, factors that index the goodness of fit between parent and child and the degree to which the partners are able to adapt to each other's affective behavior and interaction rhythms.

Triplets and the specificity of the attachment relationship. The issue of multiple birth, although related to medical risk as most triplets are born prematurely, touches upon the specificity of the attachment relationship and its centrality to infant development. Attachment relationships are built on the parent's biological tendency to focus on the needs, signals, and interaction rhythms of a single child and the infant's innate disposition to attach to a single figure (Bowlby, 1958, 1969; Klaus & Kennell, 1976). Because synchrony builds on the careful adaptation and familiarity with a specific child, it is highly sensitive to parental overload, and parents who need to attend to the unique pace and rhythms of three children at once while taking care of their physical needs are likely to have little resources for specifically-attuned parenting (Bryan, 1992; Robin, Bydlowski, Cahen, & Josse, 1991). Assessing synchrony in triplets, therefore, provides a unique window to study co-regulation and shared timing under conditions of extreme parental emotional overload. In a study following the development of triplets from birth to 2 years as compared to singletons and twins, each child was observed interacting with mother and father at 3 months and synchrony was micro-coded. Results showed that parents of triplets provided the same amounts of parenting behavior as parents of singletons and twins, in terms of gaze, positive affect, vocalization, and affectionate touch, suggesting that there is no inherent risk in the parenting system. However, the coordination of parental behavior to the infant's social cues and moments of engagement was substantially reduced (Feldman & Eidelman, 2004). Lower levels of synchrony at 3 months, in turn, predicted less optimal outcomes, in particular, less attachment behavior during a separation–reunion episode at 12 months and higher behavior problems at 2 years. Thus, the triplet condition highlights the intimacy and familiarity that underlies the synchrony experience and its dependence on the parent and child's total investment in each other and in the dyadic match.

Siblings of autistic children. Finally, in a study that examined mother–infant synchrony in siblings of autistic children at 4 months, assessed micro-analytically with time-series analysis, lower levels of coherence were found among siblings of autistic children, but only in cases where the lead–lag structure was of the infant-lead-mother-follows type (Yirmiya et al., 2006). As the infant-lead-mother-follows structure is the more optimal form of synchrony at that age, siblings of autistic children and their mothers appear to construct a less closely-fitting match, for reasons possibly related to both genetic dispositions and the childrearing context.

B. Infant psychological risk and synchrony

Risk conditions discussed in this section are those in which no specific biological or medical risk is reported. However, in many such cases there are

underlying biological or temperamental dispositions, which, combined with stressful contexts and less-than-optimal parenting, may lead to transitory maldaptation, emotional distress, or a full-blown psychiatric disorder of infancy.

Clinic-referred infants. With the growing attention to the detection and diagnosis of social-emotional disorders of infancy, the question of whether an infant can have his/her 'own' disorder, apart from disturbed contexts and disordered relationships, becomes an issue of theoretical and clinical importance (Sameroff, 1997). Infant psychiatric disorders must therefore be diagnosed hand in hand with a close evaluation of the parent–child relationship (Rutter & Sroufe, 2000). In comparing the interactions of infants referred to a community-based infant mental health clinic – most with a clinical diagnosis on Axis I that indicates a psychiatric disorder of infancy – to case-matched controls, it was found that interactions in the clinic-referred group were less optimal in various domains. Clinic infants showed higher withdrawal and lower social involvement, their mothers were more intrusive and less sensitive, and the dyadic interaction was less rhythmic, flowing, and reciprocal (Keren, Feldman, & Tyano, 2001). During a feeding session, interactions between clinic-referred infants and their mothers grew substantially worse, mothers showed more intrusiveness, and infants were even more withdrawn. These findings underscore the need to assess dyadic synchrony in a variety of caregiving contexts, and the feeding session, which elicits maternal deep worries regarding her role as a life provider, may be a useful context to observe dyadic behaviors that may not be displayed in more relaxed settings (Keren & Feldman, 2002).

Feeding disorders. Feeding disorders of infancy and early childhood represent a multifaceted disorder often accompanied by specific maternal–child relational patterns, such as low warmth and struggle for control (Chatoor, 2000). Historically, feeding problems have been grouped under the title of non-organic failure to thrive (NOFTT), theorized as related to maternal deprivation and to a cold and rejecting maternal style (Spitz, 1946). Although the close link between NOFTT and maternal deprivation is currently questionable (Wittenberg, 1990), we examined the relationships between feeding disorders and subtle difficulties in mother–infant physical intimacy, expressed in dyadic contact, proximity position, and touch patterns. These patterns were selected in light of research pointing to the associations between maternal–infant touch and contact with physical growth in humans and mammals (Feldman, 2004; Field, 1995). Infants with feeding disorders were compared with two control groups; infants with other disorders of infancy, and healthy case-matched controls (Feldman et al. 2004a). Mother and child were observed in a 15-minute free play and a 15-minute feeding session at home and the more relaxed play sessions were micro-coded with a focus on proximity position and touch patterns. In the domain of physical intimacy, mothers and children with feeding disorders showed a more disturbed profile in comparison to both children with other psychiatric disorders (mainly sleep disorders and disorders of affect) and controls. Mothers of feeding disorders children tended to place their children out of arms' reach, a position not conducive for any form of touch. The frequencies of all types of touch, including affectionate, functional, accidental, or proprioceptive touch, were substantially reduced bi-directionally: both mothers and children refrained from touching the partner. Moreover, children with feeding disorders tended to respond with withdrawal or rejection to the mother's sporadic touch, pointing to a risk for 'touch aversion' and significant disruptions in the attachment system. Moments of social gaze were also reduced, but this decrease was observed for all clinic children and was not unique to feeding disorders. However, the couching of affectionate touch within moments of mutual gaze – a pattern that integrates physical closeness and shared intimacy – was significantly reduced in cases of feeding disorders. These data provide one example for the associations between specific patterns of miscoordination with specific psychological disorders and may direct clinicians' attention to issues of touch and physical closeness in cases where feeding disorders is a possible diagnosis.

Child withdrawal. Withdrawal behavior in infants and young children is considered a risk signal for optimal development and is frequently observed among children of depressed mothers (Field, 1992). Although very little research is available on depressed infants, there are data suggesting that social withdrawal accompanied with flat or sad affect, disinterest, motor retardation, and restricted speech in young infants, when not a temporary reaction to maternal absence, is a risk signal for the development of childhood depression (Guedeney, 1997). The Alarm Distress Baby Scale (ADBB; Guedeney & Fermanian, 2001) is a brief assessment tool used to evaluate infant withdrawal during routine medical checkups. In a recent study (Dollberg et al., 2006), we examined withdrawal behavior in clinic-referred and non-referred infants in relation to patterns of mother–infant interaction. Infants who scored above the clinical cutoff on the ADBB, suggesting significant withdrawal that merits clinical attention, also showed poorer mother–infant interaction patterns observed in low social involvement, high maternal intrusiveness, and low reciprocity. The findings for social withdrawal, therefore, are similar to those reported above for intrauterine growth retardation, and show that infant negativity, expressed in either negative emotionality or withdrawn affect, is likely to

disrupt the systemic-reciprocal component of early relationships and the goodness-of-fit between the partners. However, assessment of specific interactive parameters showed that withdrawn children had the most pronounced difficulties in the domain of social gaze compared to all other infant-related risk groups. Withdrawn children rarely directed their gaze toward the mother and little or no gaze synchrony occurred. In addition, the mother's supportive presence was significantly reduced. This relational construct, modeled after Winnicott's (1956) 'holding environment', indexes the degree to which the child can use the mother's presence as a source of comfort, self-regulation, and exploration. The association between child withdrawal and decreased maternal supportive presence lends support to theoretical positions that link depression across the lifespan with early disruptions in the mother's holding function and the mother–infant reciprocity (Blatt, 2004; Stern, 1995).

Cocaine exposure. Finally, a recent study examined the coordination of social interactions in a large cohort of infants exposed to cocaine in utero as compared to controls (Tronick et al., 2005). Mothers of cocaine-exposed infants expressed more negative engagement, and cocaine-exposed dyads showed higher levels of mismatched states compared to other dyads. Heavy exposure was associated with high levels of withdrawal behavior and negative affective matching, pointing to the subtle but lasting effects of early cocaine exposure on the developing relationship.

C. Maternal risk conditions and synchrony

As dyadic systems are continuously shaped by the contributions of both partners and maternal and child's risk conditions are often interrelated, it is important to investigate the specific ways in which maternal risk conditions interfere with the development of synchrony. In particular, by postulating that self-regulation develops the basis of the maternal external regulatory function, specific difficulties in the mother's functioning may be detected by assessing micro-level patterns of interactions, their sequential dependence, and their impact on the development of self- and co-regulatory capacities.

Maternal depression. Maternal depression, being among the most prevalent disorders in the postpartum period and affecting approximately 10–12% of post-birth mothers (Burt & Stein, 2002), has received the most research on both micro-level patterns of relatedness and global assessments. Subtle difficulties in the mother–infant coordination are detected not only in cases of full-blown clinical depression but also among mothers with chronic sub-clinical symptomatology (Weinberg & Tronick, 1998). Depression slows the individual's ability to detect and respond to micro-level shifts in facial expressions (Murray & Cooper, 1997), placing depressed mothers at a particularly high risk for the development of synchrony.

Much research has demonstrated that maternal depression impacts on various aspects of mothering, including behavior (Tronick & Cohn, 1989), affect (Downey & Coyne, 1990), attachment representations (Feldman, Weller, Leckman, Kuint, & Eidelman, 1999), and perception of infant (Hart, Field, & Roitfarb, 1999). Depressed mothers tend to show more hostility, intrusive behavior, and lower responsivity to infant stress or social signals during interactions (Field, 1992; Gelfand & Teti, 1990; Goodman & Brumley, 1990; Lovejoy, Graczyk, O'Hare, & Neuman, 2000), look and vocalize to their children less often (Cohn et al., 1986; Fleming, Ruble, Flett, & Shaul, 1988), and tend to engage less in rhythmic imitation and joint activity (Field et al., 1985). The speech of depressed mothers is less focused on the infant or on acknowledging the infant's actions or abilities (Murray, Kempton, Woolgar, & Hooper, 1993), and depressed mothers have difficulty providing optimal levels of stimulation or appropriate social response during interactions (Cohn et al., 1986; Field et al., 1985, 1990; Murray & Cooper, 1997). Depressed mothers provide very little touch to their infants and when touch is observed it is often functional and not affectionate (Feldman & Eidleman, 2003; Feldman et al., 2004a). In terms of maternal affect, depressed mothers display flat, stressed, or negative facial expressions and have difficulty regulating their own emotions (Field et al., 1985; Sameroff, Seifer, & Zax, 1982; Raage et al., 1997). Such a marked decrease in all of the building blocks of synchrony – voice, gaze, affect, touch, and proximity – is likely to impact on the temporal parameters of the interaction.

Several studies showed severe disruptions to the temporal parameters of the interaction in cases of maternal depression. Moments of joint engagement between depressed mothers and their infants are typically short, with little turning to the partner for joint activity or shared affect (Gianino & Tronick, 1986). The level of matched dyadic states is similarly reduced and when states are shared it is usually the co-occurrence of negative states such as anger/protest, or uninvolvement/gaze aversion (Jameson et al., 1997; Cohn et al., 1990; Field, Healy, & LeBlanc, 1989). The degree of coherence between the mother's and infant's time-series is also reduced in the interaction of depressed mothers and their infants (Feldman, 2003; Field et al., 1990). In terms of the time-lag to synchrony, Zlochower and Cohn (1996) and Bettes (1988) found that depressed mothers took twice as long to respond to changes in their infant's behavior. The ability to repair interactive errors is also compromised in cases of maternal depression, and depressed mothers and their infants were less able to reach a matched state

or reciprocal exchange following states of mismatch (Cohn & Tronick, 1989; Jameson et al., 1997). Comparing the interactions of depressed, anxious, and co-morbid mothers with their 4-month-old firstborn child, those of the purely depressed group showed the poorest reciprocity, even in comparison with other risk conditions (Feldman, 2007). It thus appears that disruptions to the temporal parameters of synchrony are observed at all levels; the match of states, the sequential dependence, and the ongoing 'dance'.

Consistent with the theoretical hypothesis that synchrony functions as a co-regulatory experience and provides the basis for emerging self-regulatory capacities (Gianino & Tronick, 1986), children of depressed mothers were found to show difficulties in their social, emotional, and cognitive regulatory skills (Goodman & Gotlib, 1999). Moreover, the physiological substrate underlying social engagement was found to be altered in children of depressed mothers; in terms of left–right EEG asymmetry patterns; higher cortisol and serotonin levels; and lower cardiac vagal tone (Field et al., 1995, 2000). We found that 6-month-old infants of depressed mothers viewing pictures of their mothers in neutral, happy, and angry facial expressions showed stronger ERP responses in the middle component, particularly to the mother's angry face. These infants also had lower levels of synchrony during interactions with their mothers, lower baseline vagal tone, and no vagal brake, findings which suggest that the physiological systems supporting social engagement in these infants are less adaptive (Moshe & Feldman, 2006).

In a recent large community-based study (Feldman, Granat, & Gilboa, 2005), 1,000 mothers completed measures of anxiety and depression in the second post-birth day. Using an extreme-case design, 250 women at the high and low ends for depression and anxiety were contacted when the infant was 6 months old. Of those reporting high or low symptoms, 100 women were observed with their infants at 9 months, of whom 28 were diagnosed with clinical depression and 11 with an anxiety disorder. Mother–infant synchrony and the infant's regulation of joy, anger, and frustration were observed. Depressed mothers and their infants showed lower levels of synchrony in three modalities; lower gaze synchrony, less co-vocalization, and lower coordination of touch with moments of mutual gazing. The latency to the first episode of gaze synchrony, the shared gaze from which social interactions can begin, was five times longer for the depressed group, taking, on average, 60 seconds for a depressed mother to reach mutual gaze with her infant as compared to 12 seconds for the controls. Maternal gaze brake following infant vocalizations occurred five times as much in depressed mothers, and maternal gaze brake after infant social gaze occurred 2.5 times more.

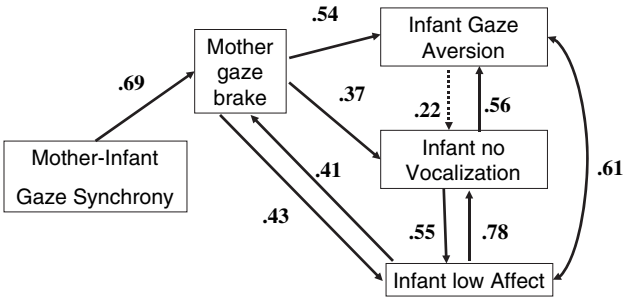

Figure 3 Sequences of mother–infant interaction in cases of mother's major depressive disorder
Coefficients represent transitional probabilities. Dotted line represents non-significant correlation

To follow the sequence of interaction and understand the micro-level dynamics of social patterns in cases of maternal depression, we computed transitional probabilities for maternal and child sequences of behaviors, beginning with the first episode of shared gaze. These findings are presented in Figure 3.

As seen, moments of shared gaze were typically followed by the mother's gaze brake, which led to the infant's gaze aversion. As infants averted their gaze they also stopped vocalizing and the level of affect dropped in a mutually reciprocal fashion. Low infant affect, no vocalization, and gaze aversion led to the mother's continued gaze brake and low involvement, creating a cycle of disengagement, flat affect, and no affect sharing. Consistent with the theory, the lower levels of synchrony in the various modalities predicted difficulties in the child's ability to regulate emotions, particularly joy and frustration.

Maternal anxiety. In contrast to research on maternal depression, very little data are available on the interaction of anxious mothers and their infants, with very few studies on the effects of maternal anxiety in the first year of life and nearly no research on the temporal parameters of synchrony in such cases. Most studies that examined the effects of maternal anxiety disorders, particularly panic disorders, focused on children beyond the first year of life and indicated that mothers with anxiety disorders showed less positivity and warmth (Hirshfeld, Biederman, Brody, Faraone, & Rosenbaum, 1997), lower support of the child's autonomy and exploration (Whaley, Pinto, & Sigman, 1999), and higher intrusion and control (Silverman, Cerny, Nelles, & Burke, 1988). In the neonatal period, anxious mothers reported more fear and worries with regards to infant safety and growth and less relationship-building behaviors and, thus, the balance between the fear and hedonic components in the maternal representation was altered (Feldman, Weller, Leckman, Quint, & Eidelman, 1999). Higher maternal anxiety during pregnancy was related to lower maternal sensitivity during mother–infant interactions

in the first months of life (Cox, Owen, Lewis, & Henderson, 1989), and anxious mothers were found to be more interfering with the infant's natural flow of play (Biringen, 1990). We found that maternal anxiety at 3 months was associated with increased maternal intrusiveness and lower infant social involvement in a dynamic way. A decrease in maternal anxiety from 3 to 9 months was related to a parallel increase in maternal sensitivity and a decrease in intrusiveness (Feldman, Greenbaum, Mayes, & Erlich, 1997), findings which suggest that anxiety tends to fluctuate and its level at any given moment may have immediate impact on the mother and child's interactive behavior.

A close evaluation of the 11 cases of maternal anxiety disorders from the community sample (Feldman, Granat, & Gilboa-Schechtman, 2005) revealed that the amount of maternal behavior was similar to that of the controls and, on some interactive components, such as 'motherese' vocalizations and the display of positive affect, anxious mothers scored higher than controls. However, the mother's behaviors were often not matched to the infant's state and signals. A typical sequence in cases of maternal anxiety was the mother's maintaining high-pitched, sing-song vocalizations for much of the interaction, regardless of whether the infant was socially responsive, gaze averting, or showing signs of fatigue.

Figure 4 presents the transitional probabilities for the sequences of mother and child's interactive behavior in cases of maternal anxiety disorder.

Similar to the findings presented for depressed mothers, specific maternal behaviors led to specific infant patterns and vice versa in a mutually-constraining way. Interactive sequences in cases of maternal anxiety were substantially shorter in duration than those observed for maternal depression. The mean duration for the interval between episodes of shared gaze was nearly eight times longer for depressed mothers than for anxious mothers, and those observed among anxious mothers nearly 3 times shorter than controls, highlighting the quick-paced nature of the interaction between anxious mothers and their infants. Interactions began with shared gaze, after which mothers immediately raised the level of arousal and added vocalization. After a period of highly arousing maternal style, infants responded with gaze aversion and decreased vocalizations. Mothers responded to infant gaze aversion by increasing the level of arousal or by looking at the infant until the infant looked back and shared gaze was resumed. This sequence details the overloaded, highly stimulating behavioral profile of the interaction with an anxious mother, a style that is not sensitive to the infant's micro-signals and does not allow for moments of quiet, neutral affect, or gaze aversion for refueling prior to the next sequence of shared relatedness.

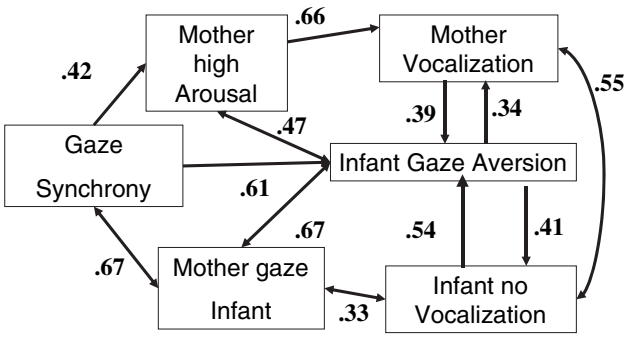

Figure 4 Sequences of mother–infant interaction in cases of maternal anxiety disorder
Coefficients represent transitional probabilities

In sum, attention to micro-regulatory patterns of parent–infant interaction in high-risk populations may open new vistas for theory and clinical practice. Specifying the unique modes of interaction in different pathological conditions – whether originating in the child, the parent, or the context – may highlight the unique areas of disruption to the co-regulatory process under different conditions and may direct clinical efforts toward more specific interventions. Furthermore, psychotherapy, as a process that unfolds in time, may benefit from attention to the non-verbal level of affective expression and from the integration of earlier patterns of relatedness with more mature forms of verbal communication (Stern et al., 1998). Research on mother–infant co-regulation and dysregulation may expand our understanding on how new relationships across the lifespan, with partners, close friends, or within a therapeutic relationship, can provide some of the missing ingredients from the individual's early experience and afford an opportunity for 'external regulation' in a specific and synchronous way.

Summary. Infants enter into the social world through the sensitive moment-by-moment adaptation of an attuned and caring adult during social interactions. Such interactions are adjusted to micro-shifts in infant affect and arousal, coalesce into patterned configurations of vocal, visual, and affective sequences, and organize the infant's biological rhythms and attentive states into a lived experience that highlights the present moment. As seen, this early experience is critical for the development of symbol use, empathy, emotional resonance, and self-regulation and lays the foundation for the child's later capacity for intimacy throughout life. The parameters of synchrony create a tight, familiar, dyad-specific process of interpersonal matching that still allows for unpredictability, creativity, and variability within the sensitive window for the development of social relatedness. Synchrony, as a time-bound experience, offers a unique co-regulatory framework for the perpetual dialogue of self and other, for the coordination of personal timing and

shared moments, and for the ongoing integration of the emerging 'dancer' and the mutual 'dance'.

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Correspondence to

Ruth Feldman, Department of Psychology and the Gonda Brain Sciences Center, Bar-Ilan University, Ramat-Gan, Israel 52900; Email: feldman@mail.biu.ac.il

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