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*Current Directions in Psychological Science* 2007 16: 340

DOI: 10.1111/j.1467-8721.2007.00532.x

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# Parent–Infant Synchrony

## Biological Foundations and Developmental Outcomes

Ruth Feldman

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**ABSTRACT**—*Synchrony—a construct used across multiple fields to denote the temporal relationship between events—has been applied to the study of mother–infant interaction and is suggested here as a framework for the study of interpersonal relationships. Defined as the temporal coordination of micro-level social behavior, parent–infant synchrony is charted in its development across infancy from the initial consolidation of biological rhythms during pregnancy to the emergence of symbolic exchange between parent and child. Synchrony is shown to depend on physiological mechanisms supporting bond formation in mammals—particularly physiological oscillators and neuroendocrine systems such as those involving the hormone oxytocin. Developmental outcomes of the synchrony experience are observed in the domains of self-regulation, symbol use, and the capacity for empathy across childhood and adolescence. Specific disruptions to the parameters of synchrony that may be observed in various pathological conditions, such as prematurity or maternal affective disorder, are detailed. A time-based, micro-analytic behavioral approach to the study of human relationship may offer new insights on intersubjectivity across the lifespan.*

**KEYWORDS**—*parent–infant synchrony; physiological oscillators; vagal tone; oxytocin; symbolic development*

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Synchrony, the temporal coordination of discrete events into a global system that regulates the expression of its various components, is a construct used across multiple fields, such as the study of gene expression, population growth, and neural networks—areas in which oscillators and time-keeping principles play a central role. Most familiar to psychologists, however, is the use of the construct in the context of parent–child relationship. Beginning with the work of Schneirla (1946) and Rosenblatt (1965) on the evolution of parenting in mammals,

synchrony has been conceptualized as an overarching process that coordinates the ongoing exchanges of sensory, hormonal, and physiological stimuli between parent and child during social interactions, providing critical inputs for growth and development of the young. Synchrony spans the period of early gestation to weaning. Beyond weaning, the preservation of parent–child relationship in mammals is expressed in the emergence of complex social organizations, not in specific parenting behaviors.

Research in the 1960s and 1970s applied this conception of synchrony to research on early social interactions in humans, focusing on the temporal coordination of nonverbal behaviors—gaze, affect, vocalizations, body movements, and arousal indicators—during caregiver–child interactions. For example, Condon and Sander (1974) found that newborns synchronize leg movements with adult speech; Wolff (1967) demonstrated specific communicative sequences in the cry patterns of newborns; and Brazelton, Koslowski, and Main (1974) addressed the repetitive-rhythmic organization of mother–infant face-to-face interaction and each individual's careful adaptation to the other's rhythms. Most theories consider the caregiver's careful adaptation to the infant's signals to be essential for infants' social-emotional growth, and several concepts—including sensitivity, co-regulation, and attunement—emerged during that period to describe such adaptation. Among these concepts, only that of synchrony highlights the time-based component in interpersonal encounters and emphasizes the ongoing organization of social behavior into repetitive-rhythmic sequences (Bernieri & Rosenthal, 1991). Yet, research on parent–infant synchrony in humans left many questions untouched and did not follow the rigorous empirical program used with other mammals. No information was available on the development of synchrony from prenatal life to the end of the first year, a period parallel to the gestation-to-weaning period of other mammals; few studies addressed the neurobiological underpinnings of synchrony; little research explored the contribution of synchrony to the emergence of complex social behaviors and higher-order cognitive capacities; and data on the specific expressions of synchrony under various risk conditions was scarce. Recent research at our lab has attempted to address this gap and to offer the construct of synchrony as an overarching, biologically

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based, micro-level behavioral framework for the study of human relationships.

### THE DEVELOPMENT OF SYNCHRONY ACROSS THE FIRST YEAR

The species-specific set of maternal behavior and the experience of social contingencies, the precursors of synchrony, are observed already in the first hours after birth, suggesting that humans are biologically prepared to engage in coordinated interactions. Human maternal behavior after birth includes gazing at the infant's face, high-pitched vocalizations, positive expressions, and affectionate touch—a behavior akin to the licking and grooming other mammal mothers engage in. Newborns engage in sporadic alert-scanning behaviors and mothers target their stimulation to the infant's alert state, providing the first contingency between the infant's internal state and the caregiver's behavior. Moreover, mothers use social contingencies to augment infant alertness. We found that mothers provided vocal and tactile stimulation for 65% of newborns' alert-scanning episodes and that infant alertness increased during the second half of a 15-minute observation as a function of maternal coordination in the first half. The amount of maternal postpartum behavior predicted infant-mother and infant-father synchrony at 3 months and the child's cognitive and neurobehavioral development across the first year (Feldman & Eidelman, 2007).

At around 3 months, infants begin to engage in face-to-face interactions and to display visual, facial, and vocal behaviors in response to social cues. At this stage, prior to the development of grasping and mobility, infants can actively engage with the world only through the give-and-take of social exchange, and coordinated interactions provide critical inputs for the maturation of the social brain (Feldman, 2007a). The temporal relationship between the social behavior of the caregiver and that of the child may take three forms: concurrent, sequential, and organized in an ongoing patterned format. Concurrent relations refer to co-occurrences of specific behaviors in parent and child, such as the co-occurrence of social gaze, vocalizing together, the matching of arousal level, or the coordination of parent affectionate touch with infant social gaze (Feldman & Eidelman, 2004). Sequential relations consider typical chains of behaviors that coalesce into repetitive "configurations." For instance, maternal positive affect typically precedes the infant's becoming positive, and infant babbling often follows maternal gaze. The patterned relationship describes the ongoing "dance" between partners as they move together toward higher or lower affective involvement—for instance, when an infant shifts from disinterest to attentive gaze and, within seconds, the mother responds with a parallel shift from quiet attention to positive arousal and stimulation. Tronick (1989) found that infants often experience interactive miscoordination, yet mismatch is typically repaired at the next second. This constant oscillation

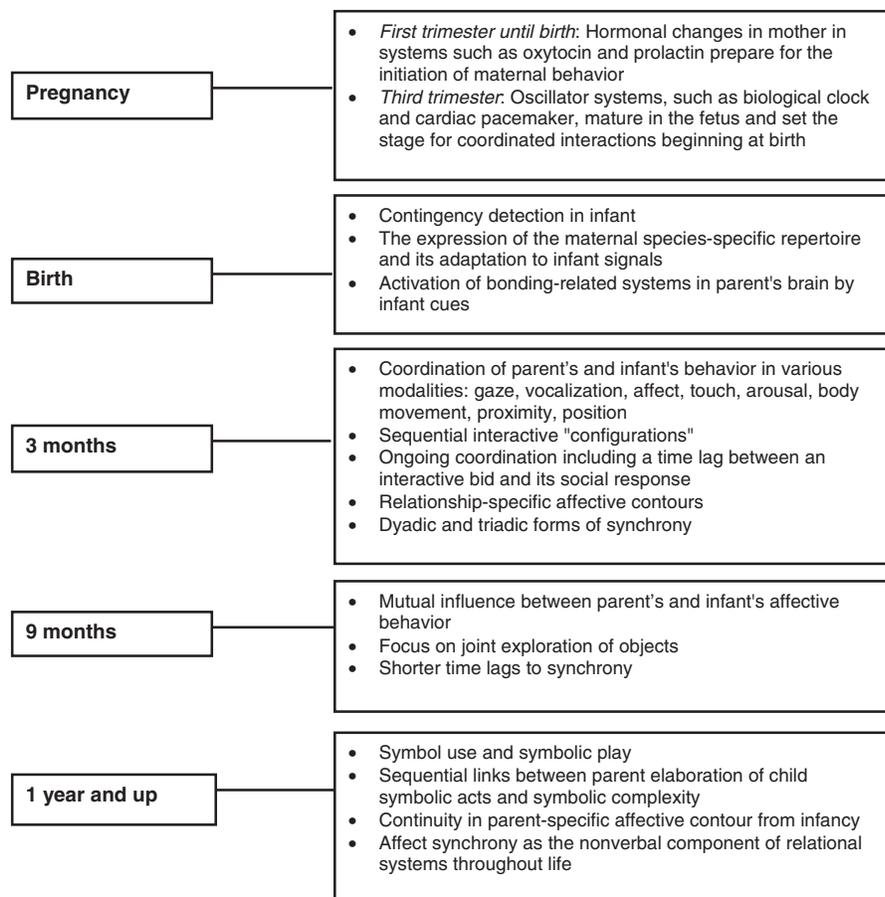
between momentary miscoordination and interactive repair marks the essence of human dialogue, to which infants are sensitized in their earliest interactions.

During the second half-year, substantial developments occur in all forms of synchrony. Co-occurrences of social gaze and co-vocalizations decrease while shared attention to objects increases. Similarly, pair-specific sequences begin to consolidate. As to the patterned relationship, the time lag to responsivity decreases, reflecting the growing familiarity with the partner's rhythms, and partners become mutually responsive to each other's behavior, indicating the infant's increasing awareness of its mother (Feldman, Greenbaum, & Yirmiya, 1999). Toward the end of the first year, as infants begin to use symbols in word and gesture, sequential relations emerge between the parent's elaboration of the child's symbolic play and an increase in symbolic complexity. Interestingly, these symbolic sequences preserve the parent-specific patterns of infancy. We found that during play with the mother, moments of positive arousal in infancy or complex symbolization at 3 years—both reflecting episodes of intense positive emotionality—were preceded and followed by mutual gaze between partners, whereas during father-infant play, moments of positive arousal were quick, frequent, and unpredictable, as were episodes of complex symbolic play in father-toddler interaction (Feldman, 2007b). It thus appears that human synchrony, like that of mammals, prepares infants to coordinate complex social acts, such as the symbolic expression of self and other, and these experiences provide the foundation for the individual's capacity to engage in intimate relationships throughout life. Figure 1 shows the development of synchrony from pregnancy to the end of the first year and beyond, beginning with its biological foundations and extending to the emergence of sequential relations between the affective and symbolic behaviors of interacting partners.

Not only are patterns of synchrony relationship-specific, but infants as young as 3 months can participate in synchronous interactions in the family setting. We found that during interactions with both parents, a change in the infant's focus between parents tended to follow change in the behavior between spouses within a lag of 10 seconds (Feldman, Masalha, & Alony, 2006). Infants, therefore, appear to possess a remarkable capacity to navigate complex social systems; they can simultaneously coordinate their behavior with the parent who is interacting with them as well as perceive the coordination of behavior between the parents and respond to it immediately.

### BIOLOGICAL FOUNDATIONS OF PARENT-INFANT SYNCHRONY

As a critical experience for growth and survival, synchrony is supported by physiological systems that enable bond formation and affiliation. We examined three systems in studies spanning early gestation to the end of the first year.

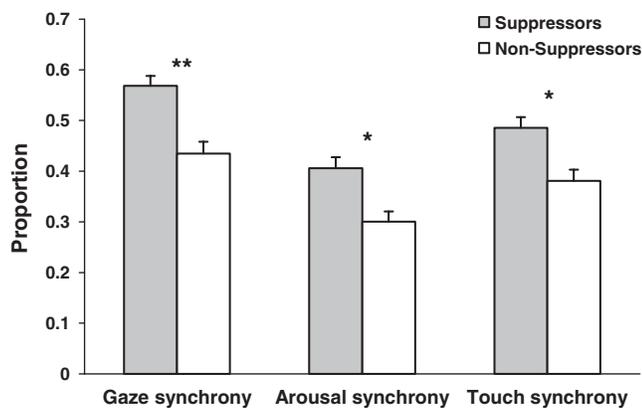


**Fig. 1.** Synchrony across the period from early pregnancy to the end of infancy (“gestation to weaning”) in humans. Hormonal changes in the mother and the emergence of physiological oscillators in the fetus during pregnancy prepare for coordinated interactions at birth. The organization of discrete social behavior into synchronous interactions begins at around 3 months and undergoes reorganization at around 9 months of age. From 1 year onward, social interactions between close partners contain two parallel levels: a nonverbal level, marked by sequential relations between the partners’ social behaviors, and a verbal level, in which sequential relations between the symbolic expressions of the interacting partners are observed.

### Physiological Oscillators

It has long been theorized, but not empirically tested, that biological rhythms provide the foundation for social rhythms. We assessed the consolidation of two physiological oscillators in the fetus during the third trimester of pregnancy: the biological clock, which organizes the sleep–wake cycle, and the cardiac pacemaker, which controls heart rhythms. The maturation of these oscillators provides the biological substrate for the regulation of arousal and the registration in real time of micro-level shifts in internal states such as hunger, blood pressure, and fatigue (Porges, 2003). The infant’s biological clock and cardiac rhythms were assessed weekly from mid-pregnancy to term in three groups of preterm and full-term infants. Individual growth curves showed that the developmental trajectory of each oscillator predicted the level of mother–infant synchrony at 3 months (Feldman, 2006), confirming to the role of oscillator systems in providing the basis for synchrony.

In a recent study, 122 mothers and their infants were observed in the “face-to-face–still-face” paradigm while cardiac output was assessed from both partners. In this paradigm, the mother interacts freely with the infant for 3 minutes, then refrains from facial expressions and maintains “still face” for 2 minutes, and finally re-engages. A surprising finding was that, in pairs displaying high synchrony during free play, mother and infant’s heart rates became synchronized, so that an acceleration or deceleration in the infant’s heart rhythms were followed by acceleration or deceleration in the mother’s heart rhythms within less than 1 second. Similar to the role of maternal proximity in organizing infant physiology in other mammals, the mother’s careful adaptation to infant social cues regulates the infant’s heart rhythms, and this experience is likely internalized as an emotional sense of security that accompanies the child throughout life. Another index derived from the cardiac output was vagal-tone suppression—a decrease in heart-rate variability



**Fig. 2.** Gaze synchrony (proportion of time mother and infant share social gaze), arousal synchrony (proportion of time mother and infant are in the same level of arousal—positive, neutral, or negative), and touch synchrony (proportion of time mother touches the infant affectionately while infant is looking at the mother) as related to suppression or non-suppression of cardiac vagal tone. Cardiac vagal tone is a specific measure of heart-rate variability. A decrease in vagal tone from a nonstressful episode to a stressful episode serves as a biomarker of the individual's emotion-regulation capacities.

in response to a stressful event, which serves as a biomarker of the autonomic nervous system's ability to regulate emotions (Porges, 2003). Infants who showed vagal tone suppression during the stressful still-face episode engaged in more synchronous interactions in terms of arousal matching, shared gaze, and touch synchrony, pointing to the role of autonomic regulation in facilitating the infant's capacity to partake in the synchrony experience (Fig. 2).

### Bonding-Related Hormones

Oxytocin, a neuropeptide implicated in social affiliation, plays a role in animal bonding; yet its role in maternal–infant bonding in humans has been less studied. In the first longitudinal study to assess plasma oxytocin in relation to mother–infant interaction, we followed 62 women at first trimester of pregnancy, last trimester, and first postpartum month. Mothers who had high levels of oxytocin in early pregnancy tended to maintain these high levels in late pregnancy and afterwards, to engage in more maternal postpartum behaviors, and to synchronize their behaviors with the infant's state more than did mothers with low initial levels of oxytocin. These mothers also reported having more vivid and pleasurable thoughts of their infants (Feldman, Weller, Zagoory-Sharon, & Levine, 2007). As it does in animal mothers, oxytocin seems to prepare new human mothers to initiate maternal behavior, which starts the process of maternal–infant bonding.

### Brain Activation

An fMRI study of parents responding to their own versus anonymous infant pictures indicated that parents who engaged in synchronous interactions showed higher activation in the

superior temporal gyrus, anterior cingulate cortex, thalamus, and midbrain—subcortical regions implicated in parenting, empathy, and emotion regulation (Swain et al., 2007). In a study of event-related potentials (ERPs, brain electrophysiological recordings time-locked to a particular stimulus), 6-month-old infants observed pictures of their mothers in neutral, happy, sad, and angry expressions. Afterward, mother–infant interactions were videotaped and synchrony was assessed. Among infants of depressed mothers, minimal levels of synchrony were detected and these infants also showed a greater ERP response to their mothers' angry face. Thus, the experience of synchrony may have a lasting impact on the infant's brain, particularly during the early plastic period of brain maturation. Overall, the findings across multiple physiological systems demonstrate that synchrony is supported by bonding-related physiological and endocrine systems and depends on time-keeping mechanisms that maintain positive mood, social orientation, and attention to micro-level shifts in relational behavior.

### SYNCHRONY, DEVELOPMENTAL OUTCOMES, AND RISK CONDITIONS

In several cohorts we found long-term effects of parent–infant synchrony on development across childhood and up to adolescence. Mother–infant synchrony at 3 and 9 months predicted self-regulation at 2, 4, and 6 years, assessed in tasks that required children's compliance to maternal requests (“toy pick-up”) and prohibitions (refraining from touching attractive toys or sweets); IQ measured at 2 and 4 years; the complexity of symbolic expressions during play at 3 years; and the child's use of words that reflect internal state at 2 years (e.g., “I feel”, “you think”), a precursor of theory-of-mind skills (Feldman & Greenbaum, 1997). Synchrony with the mother and father at 3 months correlated with more optimal attachment behavior at 1 year and with lower levels of behavior problems at 2 years, findings suggesting that synchrony may provide a buffer against psychosocial maladjustment. Finally, a follow-up from 3 months to 13 years pointed to the role of synchrony in shaping the adolescent's capacity for empathy, suggesting that synchrony sensitizes infants to the emotional resonance that underlies human relationships across the lifespan. Taken together, these findings underscore the lasting impact of early affective matching on complex social processes of self-regulation, empathy, and symbol formation, domains that require individually matched experiences for optimal growth (Feldman, 2007a).

The parameters of synchrony are not only useful in predicting infant development but are sensitive to risk conditions stemming from both parent and child. Premature infants, for instance, tend to engage in short, frequent mutual gazes; mothers and preterm infants typically break mutual gaze immediately after its initiation, and their interactions are characterized by lower synchrony between the partners (Lester, Hoffman, & Brazelton, 1985). Parents of triplets often display normative amounts of social

behaviors but these are uncoordinated with the infant's signals. The lower levels of synchrony triplets experience predicted lower social-emotional adjustment at 2 years (Feldman & Eidelman, 2004)—findings that highlight the importance of the parent's exclusive focus on the child for the development of synchrony.

With regards to the state of the mother, maternal depression is often associated with flat affect and diminished maternal behavior. Among clinically depressed mothers, moments of shared gaze were rare, few relational sequences appeared, and no patterned relationships of ongoing behaviors were detected. Clinically anxious mothers, on the other hand, engaged in more social behaviors such as smiling and vocalizing, but their stimulation often occurred when their infants signaled a need for rest (Feldman, Granat, & Gilboa-Schechtman, 2005). The parameters of synchrony, therefore, are sensitive to developmental risk, and different pathological conditions present unique relational profiles. These findings may be used to devise specific interventions to train parents to read their infants' micro-level signals and respond synchronously; such interventions have been shown to increase maternal sensitivity and infant social competence in a clinical context (Dollberg, Feldman, & Keren, 2006).

### CONCLUSIONS AND FUTURE DIRECTIONS

The emergence of the self from its relational matrix is a complex process that integrates multiple physiological systems with carefully matched social behaviors. This ongoing interchange between self and other undergoes transformations across early childhood, from early nonverbal coordination to the matching of complex symbolic expressions, while preserving the underlying temporal structure of the communication and its physiological underpinning. Further work is needed on the neurobiology of synchrony—in systems such as mirror neurons or internal oscillators—and on the effects of synchrony on the developing brain. Finally, the impact of parent–infant synchrony on the adult's intimate relationships and ultimate parenting is among the most exciting, theoretically relevant questions for developmental research.

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- Fogel, A. (1993). *Developing through relationships*. Chicago: University of Chicago Press. An integrative account of the temporal dynamics of mother–infant interaction from a dynamic-systems perspective.
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**Acknowledgments**—Research is supported by the March of Dimes Foundation (#12-FY04-50), the U.S.–Israel Bi-National Science Foundation (2001/241 and 2005/273), and the NAR-SAD foundation.

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