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The Relevance of Touch for Development and Health

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Maternal Touch and the Developing Infant

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Touch is the most basic mammalian maternal behavior. As soon as an infant is born, mammalian mothers begin to engage in the species-typical repertoire of maternal behavior, and these postpartum behaviors consist primarily of close physical proximity and the provision of maternal touch. Being such a widespread mammalian behavior, early maternal touch must carry important implications for survival and adaptation and contribute to the growth and development of the young. Moreover, this postpartum maternal repertoire must be supported by a unique neurobiological system of parenting that includes the functioning of specific genetic markers, brain circuitry, hormonal expression, autonomic response, and the epigenetic programming of stress and affiliation genes. Maternal touch patterns are among the most evolutionarily conserved behaviors and, as such, there is marked consistency in the genetic, neuroendocrine, and brain circuitry between humans and other mammals. Of particular interest is the feedback loop that begins with maternal touch and contact; continues with the effects of contact on organizing the infant's physiology and behavior and establishing attachment-related cues; and culminates in the effects of these organized infant social and exploratory behaviors on sensitizing maternal and infant's bonding-related physiology [e.g., the oxytocin (OT) response], thereby forming the unique mother–infant bond (Feldman, 2010a). Such consistency in the role of maternal touch between humans and other mammals renders research in animal models particularly useful for understanding the biological underpinnings of early touch and contact and their effect on shaping the infant's capacity for social affiliation and stress modulation throughout life. AQ1

Not only are maternal touch and contact central to our evolutionarily based biology, maternal-infant physical closeness and the mother's affectionate touch are central components of the human cultural heritage. Throughout human history and across cultural communities, images of maternal-infant physical proximity—in sculptures, drawings, carvings, and ink paints—are deeply rooted in our collective unconscious and serve as the primary symbol for the human capacity to love. Maternal touch, therefore, is not just one more thing mothers do: It is the basic channel for the expression of parenting and serves as the bedrock of the individual's future capacity to provide love and nourishment to future attachment relationships. Attachment relationships, in turn—at least according to some perspectives—provide the motivating force that guides human development and defines the apex of the human condition (Bowlby, 1969; Feldman, 2010a; Winnicott, 1956).

This chapter presents research conducted at our lab for over a decade on two important areas of maternal touch: its role as a central component in the repertoire of maternal behavior and the impact of an intervention called "Kangaroo Care (KC)" or skin-to-ski mbvcdn AQ2 contact. In the first section, studies that address the expression of early touch and contact by human mothers, the biological substrates of touch in parenting behavior, and the contribution of early touch and contact to infant development across childhood and into adolescence will be discussed. In the second section, results from a longitudinal follow-up of premature infants who received the KC intervention will be presented, including the impact of KC on the preterm infant's self-regulatory competencies, neuromaturation, and physiological regulation, as well as on maternal outcomes and the parent–child relationship.

Overall, our empirical studies in humans follow two lines of research in animal models. The first is the elegant empirical program of Hofer and colleagues (1995), which demonstrated, in over 40 years of systematic research, that the mother's proximity and physical presence contain a set of biobehavioral provisions, such as maternal body heat, nursing, smell, or tactile contact—and that each provision regulates a specific physiological system in the pup, including the biological clock, heart rhythms, thermoregulation, or attention and exploration. By careful separation and systematic manipulation of each component of the maternal presence, the researchers were able to chart direct links between specific maternal provisions and the infant's biobehavioral maturation. This conceptual frame guided our research on the KC intervention and its sequelae. Premature birth and the ensuing separation between mother and child was conceptualized as a "natural experiment" for the effects of maternal bodily contact on infant development during a period of early and persistent maternal absence. Our intervention was based on the assumption that the provision of maternal proximity during this period of early and persistent deprivation would contribute to the maturation of the infant's physiological support systems that provide the basis for higher-order functions, such as exploration, attention, socialization, and behavior control. We expected similar effects following the KC intervention as those observed in other mammals following handling during periods of deprivation.

The second influence on our research on the effects of maternal touch as a more active and ubiquitous component of the maternal postpartum repertoire is the empirical work of Meaney and colleagues (Champagne, 2008; Meaney, 2001). In a series of creative and seminal studies, these researches showed that "licking and grooming," the typical touch behavior of parturient rat mothers, was transmitted from mother to daughter through mechanisms of social experience rather than through genetics and that crossfostering studies showed that higher licking and grooming was associated with higher OT receptor densities in brain areas central for the expression of parenting, including the paraventricular nucleus of the hypothalamus, the lateral septum, and the bed nucleus of the stria terminalis. Finally, these studies demonstrate that early maternal licking-and-grooming behaviors shape the infant's stress management systems through epigenetic influences and that the adult's capacity to handle stress is formed early in life through such patterns of maternal touch. Adapted to human research, these studies suggest that the human infant's susceptibility to stress and ultimate skill at regulating aversive life circumstances may have their roots in the mother's early tactile contact. Overall, this perspective underscores the role of early experience—particularly as related to touch and contact—in shaping the neurobiological system that supports the human capacity for social affiliation.

Finally, it is important to note that, although both continuous maternal proximity and active forms of touch are central components of the mother's early repertoire that provide essential environmental inputs for physiological and behavioral regulation, there are wide differences between cultures in patterns of parental touch. As will be discussed below, some cultures promote more ongoing physical contact between mother and infant whereas others engage more in active forms of touch. Such differences reflect wide cultural variations in the philosophical meaning systems that shape parenting, in the cultural perceptions on the nature of the self and its relation to the social world, and in the degree of separation between mother and child each culture considers acceptable during the first months of life (Feldman & Masalha, 2010; Tronick, 1995).

TOUCH AS A CENTRAL COMPONENT OF THE MATERNAL REPERTOIRE

Early Maternal Touch and Its Contribution to Infant Development

Immediately after the birth of a human infant, mothers begin to engage in typical maternal behaviors which in our species include holding the infant in a cradling position, gazing at the infant's face and body, expressing positive affect, emitting "motherese" (high-pitched vocalizations), and providing affectionate touch. The combination of these behaviors can be described as the "maternal postpartum repertoire" (Feldman, 2010a). Affectionate touch, the human analogue to the "licking-and-grooming" behaviors of rat mothers, is the most prevalent active behavior in the maternal constellation, apart from social gaze at the infant's face and body, which provides the framework for social relatedness. These two behaviors—social gaze and affectionate touch—often co-occur and establish the basis for interpersonal mutuality between mother and infant in the first days after birth. Mothers use the maternal behavior constellation in general, and affectionate touch in particular, in concordance with the infant's social signals and adapt the provision of maternal behavior to the newborn's scant moments of attention. We found that during social interactions, newborns maintain social gaze for ~10% of the time, yet mothers provide nearly 70% of their maternal behavior during these moments of infant alertness. Such contingency provides infants their first experience of coordination between their own state and the responsive behavior of the social environment (Feldman & Eidelman, 2007). Further, the provision of maternal postpartum behavior and affectionate touch forms the basis for the development of a synchronous relationship between mother and child. The amount of maternal postpartum behaviors shaped the degree of mother–infant synchrony and level of maternal affectionate touch at 3 months. The mother's postpartum behavior also predicted the level of father–infant synchrony and paternal touch, pointing to the importance of early touch in setting the framework for the infant's engagement in multiple attachment relationships across infancy (Feldman & Eidelman, 2007).

Touch in the early neonatal period contributes to the infant's neurobehavioral, cognitive, and social–emotional growth. For instance, we found that the provision of breast milk in premature infants was associated with an increase in maternal postpartum behavior in general and was especially conducive for increasing maternal affectionate touch, which is generally low among mothers of premature infants. Infants who received more breast milk showed higher neurobehavioral maturation on the Neonatal Behavior Assessment Scale (Brazelton, 1973) and showed better cognitive development at 6 months. The effects of breast milk on development was thought to stem from two sources—a direct path that involves the effects of the specific proteins, enzymes, micronutrients, lipids, and long-chain polyunsaturated fatty acids included in breast milk which are critical for the growth and development of premature infants (Heird, 2001) and the indirect effect of increasing maternal affectionate contact, which in turn contributes to more optimal outcomes. Each of these paths was found to be uniquely predictive of cognitive development across infancy (Feldman & Eidelman, 2003b). Similarly, following infants at multiple time points across the first year, it was found that more maternal postpartum behavior, including affectionate touch, set the trajectory of maternal behavior on a more optimal path, and mothers who provided more postpartum touch were more sensitive and reciprocal at 3, 6, and 12 months. Using structural analysis, the latent factor of maternal sensitivity, measured from birth to 1 year, was found to predict better cognitive development and more complex symbolic play (Feldman, Eidelman, & Rotenberg, 2004).

At around 3 months of age, infants begin to engage in synchronous face-to-face interactions with their parents and such exchanges involve the coordination of nonverbal social signals in the different modalities, including gaze, touch, affective expression, and vocalizations. Touch synchrony—the coordination of the parent's affectionate touch with the parent and child's social gaze—becomes an important component of early interactions by which touch is integrated into the parent–infant mutually responsive system (Feldman, 2007). The experience of touch synchrony and missynchrony—moments in which mother provides stimulatory touch while the infant gaze averts and signals a need to rest—are related to physiological support systems that index the stress response, such as cortisol and respiratory sinus arrhythmia (RSA; Feldman, Singer, & Zagoory, 2010), and contribute to the development of brain circuits that support the development of social engagement (Johnson et al., 2005). Indeed, touch synchrony at 3 months with both mother and father was related to behavior adaptation at 2 years as assessed by lower externalizing and internalizing symptoms (Feldman & Eidelman, 2004), possibly because the integration of affectionate contact into the synchronous exchange helps orient the infant to the social world and its rules of conduct. Finally, touch synchrony between mother and infant at 3 months was found to predict the child's level of empathy at 5 years, as measured by the child's empathic understanding of the other's perspective during conflict discussion with the mother, empathic responding to a "painful" expression of the experimenter, and prosocial solutions to moral dilemmas that involve assistance to another person at a cost for the self. It is thus possible that the integration of affectionate touch into a mutually responsive early social system helps regulate the child and, further, that personal social signals become interwoven into a meaningful interpersonal experience that prepares the child for responsible engagement in the social world.

During the first year of life, maternal touch patterns undergo significant development. In a study that followed patterns of maternal touch at 3, 6, 9, and 12 months, infants were videotaped in caregiving and play sessions. Caregiving sessions were microcoded for nine patterns of maternal touch that were aggregated into three constructs—affectionate touch, stimulatory touch, and instrumental touch—while play sessions were coded for maternal sensitivity and dyadic reciprocity. Both maternal affectionate and stimulatory touch decreased markedly after the first 6 months of life, hand in hand with the significant increase in dyadic reciprocity (Ferber, Feldman, & Makhoul, 2008). Possibly, the affectionate touch patterns that define the maternal postpartum repertoire play a significant role as central components of the maternal style during the first 6 months of parenting. After that stage, with the development of infant mobility, intentionality, shared attention, and intersubjectivity, other forms of mutuality gradually take central stage and affectionate contact, although remaining an important component of close relationships throughout life, may no longer be the most prevalent maternal behavior.

Finally, maternal affectionate touch is one among several codes that compose the Mother Sensitivity construct in our global coding system for the analysis of parent–child interactions (Coding Interactive Behavior, or CIB; Feldman, 1998). Conceptually, this inclusion suggests that affectionate touch is one among several components that shape the maternal sensitive style, which serves as the cornerstone of infant social–emotional growth (Bowlby, 1969), but also that it does not stand alone. The specific components of the sensitive style undergo developmental changes, but its suitability and adaptiveness to the child's needs and signals remain. Mother sensitivity measured in the first 6 months, including affectionate touch, was found to predict cognitive development from 6 months to 5 years (Feldman & Eidelman, 2009), social competence with peers in kindergarten (Feldman & Masalha, 2010), lower behavior problems in the preschool years (Feldman & Masalha, 2007), better emotional adjustment in adolescence, and lower depression in adolescence (Feldman, 2010b). Maternal sensitivity is also an individually stable construct and mothers who were sensitive at 3 months continued to be the same in adolescence (Feldman, 2010b), indicating that early affectionate touch is integrated into the mother's stable and predictable style that supports growth throughout childhood and adolescence.

Variability in Parent–Infant Touch Patterns

Differences between maternal and paternal touch. Although both mothers and fathers provide affectionate touch to their infants and, by 3 months of age, engage in touch synchrony, there are differences in the typical patterns of maternal and paternal touch in both humans and biparental mammals. While mammalian mothers in species such as rats, lambs, and primates engage in grooming and contact forms of touch, fathers in biparental species provide stimulatory contact, tend to carry the infants in space, and encourage exploratory behavior (Mastripieri, Hoffman, Anderson, Carter, & Higley, 2009; Ziegler, 2000). Human fathers tend to engage in rough-and-tumble play, manipulate the infant's extremities, throw the infant in space, and encourage exploration (Lamb, 1977). Similarly, synchronous interactions between mothers and fathers differ in their temporal pattern. Mother–child interactions typically contain face-to-face exchanges between mother and child, involve rhythmic oscillations between low and medium arousal, and contain one peak of high positive arousal that is framed by a social gaze (Feldman, 2003). Father–child interactions, on the other hand, are quick; include several high peaks of positive arousal that appear at random, such as when father throws the child in air or plays with the child's extremities in a highly arousing manner; and focus on exploring the environment rather than the partner's face (Feldman, 2003). It is possible that infants need to experience interactions that are rhythmic, social, and predictable as well as those that are quick, unpredictable, and oriented to the outside world for optimal social–emotional growth. As will be discussed later, these maternal and paternal touch patterns are differentially related to the oxytocinergic system that supports bond formation in humans and mammals.

Dyadic and triadic touch. Triadic family interactions provide infants their first opportunity to engage in a multiperson social system and predict the development of children's social competence in the peer group (Feldman & Masalha, 2010). In a study of mothers, fathers, and their first-born child at 4 months, we examined synchrony in triadic social behavior at the microlevel. We found that infants spent the same amount of time playing with mothers and fathers during family sessions and that mothers and fathers provided similar amounts of social behavior, including affectionate touch.

Cultural variability. Cultures vary widely in patterns of maternal touch and contact. In more traditional societies, mothers maintain full bodily contact for a major portion of the day and cosleep with the infant at night throughout the first months or even years of life (LeVine, 2002). Such continuous contact serves a soothing function and reduces infant distress. It also emphasizes the inseparability of mother and child and represents an underlying interdependent orientation that stresses the connectedness between members of the cultural group. In more individualistic societies, on the other hand, mothers engage in more active forms of touch and do not maintain continuous contact, reflecting an independent orientation to childrearing and the self (Markus & Kitayama, 1991).

Observing family interactions among Israeli and Palestinian parents and their 5-month-old firstborn child in their home ecology, we found that Palestinian families positioned themselves in a way that continuous contact was maintained between both parents and the infant, and among the spouses, but that this position did not allow for face-to-face interactions or the expression of active touch, mutual gazing, or covocalizations. The continuous contact indeed reduced the infant's negative emotionality, and Palestinian infants fussed and cried significantly less than Israeli infants. On the other hand, Israeli couples sat in a position that enabled face-to-face interactions between each member of the triad and provided more affectionate touch. Infants reached higher levels of both positive and negative arousal, as active forms of touch are physiologically more stimulating than passive contact. These patterns reflect a more independent cultural orientation, one that emphasizes autonomy and social relationship between separate individuals who coordinate their behavior with each other (Feldman, Masalha, & Alony, 2006; Feldman, Masalha, & Nadam, 2001). Deep-rooted cultural philosophies on the nature of the self and its developmental goals may be transmitted from parents to children in the first months of life during their first social encounters, being expressed primarily through variations in patterns of parental touch and contact.

Biological Correlates of Maternal Touch: Hormonal, Autonomic, and Brain Systems

Neuroendocrine pathways: OT, cortisol, and prolactin. Animal studies have implicated the neuropeptide OT in the process of bond formation in a range of mammalian species, yet its role in human attachment has received less attention (Carter & Keverne, 2002; Insel & Young, 2001). In mammals, maternal touch has been closely linked with the expression of OT both centrally (in the brain) and peripherally, and our recent research points to the involvement of early parental touch in the expression of OT in humans. In a longitudinal study assessing OT across pregnancy and the postpartum, we assessed plasma OT from women at three time points: first trimester, last trimester, and first postpartum month. OT levels were highly stable among individuals and showed no mean-level change, and OT at the first trimester predicted the amount of maternal postpartum behavior, including gaze at infant face, positive affect, "motherese" vocalization, and affectionate touch. These data suggest a "priming" effect for OT across pregnancy for the emergence of the species-specific maternal repertoire in human mothers, similar to its role in other mammals (Feldman, Weller, Zagoory-Sharon, & Levine, 2007). Cortisol was also assayed from the maternal blood at early pregnancy, later pregnancy, and the postpartum. In contrast to OT, higher cortisol levels among mothers were related to the amount of maternal instrumental–functional touch they used (i.e., performing a task such as wiping the child's mouth or picking the infant up from a chair) rather than on touch that expressed love and affection. This finding points to an association between higher levels of stress in mothers and lower levels of the growth-promoting affectionate touch style. In a second study on OT and bond formation in mothers and fathers, 160 new parents (80 couples) were seen twice, in the first postpartum month and again at 6 months after the birth of the first child. At both time points, parents' plasma OT was assayed. Parents also were videotaped interacting with their infants in various contexts and were interviewed regarding their attachment to the infant. Contrary to our expectations, fathers and mothers had comparable levels of OT at both time points and baseline levels of OT were highly individually stable in both mothers and fathers. Most interestingly, husband and wife's OT levels were inter-related, suggesting a mutual influence of neuroendorcine pathways, or "endocrine fit," between partners. OT levels in the first postpartum weeks were related to the parent-specific behavioral repertoire. While maternal OT was related to the mother's affectionate contact, paternal OT correlated with stimulatory contact and father's encouragement of exploration, suggesting that the parent-typical behavioral repertoire is linked in some way to OT expression (Gordon, Zagoory-Sharon, Leckman, & Feldman, 2010a).

In a recent study, we examined whether the OT response in human parents is consistent with those observed in mammals. One hundred and twelve mothers and fathers engaged in a 15-minute play-and-contact session with their infants; OT was assessed before and after play. Similar to the findings from Meaney and colleagues (Francis, Champagne, & Meaney, 2000), which showed that natural variations in maternal licking and grooming were related to systematic differences in brain OT, we found that OT increased after the play interaction among mothers who provided a high level of affectionate touch (more than 67% of the time) but did not increase among mothers who provided a low level of affectionate touch. Among fathers, OT increased in those who provided high levels of stimulatory contact but not in those who provided minimal contact, similar to the findings for biparental fathers (Feldman, Gordon, et al., 2010). Thus, the parent-typical forms of touch—affectionate in mothers and stimulatory in fathers—seem to be associated with both baseline OT and with OT release following parent–infant contact.

Two additional studies highlight the associations between OT and parental touch. In the first, salivary OT was sampled from parents (mothers and fathers) and their 6-month-old infants before and after a session of parent–infant interaction. Results are the first to demonstrate not only measurable and consistent OT levels in infants, but a crossgeneration transmission of the OT response between human parents and their infants. Parent and infant's OT were correlated at both the pre- and post-interaction assessment and when parent–child interaction was characterized by a higher level of synchrony, including the integration of parental affectionate touch matched with parent and child's social gaze and a greater increase in both parent and child's OT was observed after the interaction (Feldman, Gordon, & Zagoory-Sharon, 2010). AQ3

Finally, we assessed the relation between maternal and paternal plasma OT and touch during triadic family interactions among parents and their 6-month-old firstborn child. Higher triadic synchrony, defined as moments of coordination between physical proximity and affectionate touch between the parents as well as between parent and infant while both parent and child are synchronizing their social gaze, was predicted by both maternal and paternal OT. Among mothers, triadic synchrony was also independently related to lower levels of CT. Results highlight the role of OT in the early formation of the family unit at the transition to parenthood. These findings further demonstrate the importance of the oxytocinergic system and touch among family members for the formation of the family unit during the transition to parenthood (Gordon, Zagoory-Sharon, Leckman, & Feldman, 2010b).

The effect of maternal touch on the infant's stress response during simulated maternal deprivation was assessed among two groups of mothers and their 6-month-old infants. In the first group, infants were assessed in the typical still-face paradigm, in which mother and infant interact for 3 minutes, mother then maintains a still-face for 2 minutes, and mother and infant finally resume play for 2 minutes. Cortisol was measured at baseline, reactivity, and recovery. In the second group, mothers maintained tactile contact during the still-face episode of the procedure. When maternal unavailability during the still-face episode was accompanied by maternal touch, infants showed a more attenuated stress response and returned to baseline levels more rapidly, while the stress response in the still-face-without-touch group was significantly higher and cortisol further increased, rather than decreased, at recovery. Thus, maternal touch appears to contribute to two elements that are considered central to resilience in mammals: attenuating the magnitude of the stress response and enabling a quick recovery to baseline states following stress (Feldman, Singer, & Zagoory, 2010). Similar findings for cortisol and stress emerged in a 10-year follow-up of the KC intervention and will be briefly described later. Other hormones involved in mediating rewards in humans and mammals, such as opioids, as well as hormones associated with hormones related to parenting. Recently, we found correlations between OT and prolactin in new fathers and correlations between prolactin and the father's encouragement of toy exploration during interaction with the infant (Gordon, Zagoory-Sharon, Leckman, & Feldman, 2010c). Similarly, hormones associated with the regulation of hunger and satiety, such as cholecystokinin (CCK), have also been associated with touch and contact in mammals (Weller & Feldman, 2003). In a recent study, we found associations between parental OT and CCK in a sample of new parents, suggesting that the formation of the parent–infant bond involves inputs from reward pathways and brainstem-mediated homeostatic systems that combine to create the selective and enduring parent–infant bond (Feldman, 2010a).

Autonomic response: RSA and the vagal brake. RSA, or cardiac vagal tone, measures the respiratory component in heart-rate variability and is thought to index the regulatory influences of the parasympathetic nervous system on the behaving organism and to provide a biomarker of the individual's emotion regulatory skills. Higher baseline vagal tone has been associated with better regulatory capacities and more optimal social engagement (Porges, 2003). The vagal brake—the degree of change in vagal tone in response to stressful situations—indicates the degree of stress the system experiences and the capacity of the system to mobilize sufficient energies to respond to environmental challenges.

Maternal postpartum affectionate touch, affect synchrony at 3 months, and affectionate touch at 3 months among mothers and fathers were predicted by the infant's baseline vagal tone in the neonatal period (Feldman & Eidelman, 2007). These findings indicate that the infant's biological dispositions toward social engagement and emotion regulation play a role in eliciting the parental response, particularly touch patterns. Similarly, the development of vagal tone throughout the gestational period in premature infants was related to the degree of mother–infant synchrony at 3 months (Feldman, 2006).

In the aforementioned study of simulated maternal deprivation—that is, using the still-face with and without touch—infant vagal tone was measured during baseline, reactivity and recovery. Similar to the findings for cortisol, maternal touch during the still-face episode decreased the magnitude of the change in vagal tone and the autonomic response returned quickly to baseline. This finding points to the multidimensional effects of maternal touch on attenuating the infant's stress response during moments of maternal unavailability (Feldman, Singer, et al., 2010).

Brain circuitry for parenting and touch: Functional magnetic resonance imaging studies. Animal studies and the emerging functional magnetic resonance imaging (fMRI) literature in humans have identified key brain areas that are central for parenting which include the hypothalamus, thalamus, anterior cingulate cortex, septal region, midbrain, and medial preoptic area—regions identified on the basis of knockout models and lesion studies in rodents (Swain, Lorberbaum, Kose, & Strathearn, 2007). Research from our group assessing the brain response of parents to infant stimuli, particularly pictures and cries, has validated these areas as central to the neurobiology of human attachment (Swain et al., 2004a, 2004b; Swain, Leckman, et al., 2007).

Two recent studies highlighted maternal touch in relation to these key parenting brain areas. The first assessed the effects of breastfeeding, associated with increased physical contact and affectionate touch, on brain activations and maternal sensitivity. Two groups of breastfeeding and formula-feeding mothers were scanned during the first postpartum month and again at 3–4 months postpartum, and mother–infant interactions were videotaped. Breastfeeding mothers showed greater activations in response to their infants' cries, including the bilateral thalamus, periaqueductal gray, globus pallidus, putamen, caudate, right amygdala, left anterior cingulate gyrus, and prefrontal cortex. Greater activations in these areas, in turn, predicted higher maternal sensitivity at 3 months, suggesting a link between breastfeeding, maternal contact, and the reorganization of the maternal brain in preparation for motherhood (Kim, Feldman, Mayes, Swain, & Leckman, submitted for publication).

Similar findings emerged from a very recent study in which mothers observed themselves interacting with their infant while functional connectivity analysis assessed the mother's brain response during moments of affectionate touch. In response to their own affectionate touch of the infant, mothers of 4- to 6-month-old infants showed the expected activations in primary and secondary somatosensory cortices and in premotor and motor cortices. However, activations in the parenting network were detected *specifically during moments of affectionate touch;* activated areas included the left and right globus pallidus, putamen, posterior cingulate cortex, left and right insula, uncus, parahippocampal gyrus, and the right amygdale. Similar to the findings for infant stimuli, the prefrontal cortex also showed higher activations when mothers observed interactions that included affectionate touch between themselves and their infants (Atzil, Hendler, & Feldman, 2010).These new data suggest that the specific maternal brain circuitry responds as a cluster to the most primary mammalian maternal behavior—the provision of the species-specific form of touch.

Maternal Touch and Developmental Psychopathology

The most prevalent breeches in maternal-infant bonding are premature birth and maternal postpartum depression (PPD), each of which occurs in about 10–15% of the population in industrial societies (March of Dimes, 2006; Serretti, Olgiati, & Colombo, 2006). In both conditions, mothers have difficulty touching or making contact with their infants.

Premature birth. Prematurity involves disruption to the physical contact between mother and child during the child's postnatal hospitalization. This break in contact typically results in lower levels of maternal affectionate touch—and at times in increases in maternal instrumental, functional, and intrusive touch—even even after physical contact is resumed (Feldman, 2004). Aforementioned studies highlight the centrality of maternal touch for the infant's optimal growth. Reduced maternal touch, particularly in combination with the preterm infant's already compromised physiology, may place these infants at marked developmental risk (Weiss, 2005; Weiss, Wilson, & Morrison, 2004).

Several studies in our lab addressed touch patterns between parents and their premature infants. Both in the neonatal period and at 3 months of age, mothers and fathers of premature infants provided less affectionate touch to their infants than parents of full-term infants (Feldman & Eidelman, 2007). However, mothers of preterms varied in their ability to engage in affectionate touch. For instance, mothers who resolved the trauma of premature birth (i.e., were able to discuss the experience with openness, coherence, and richness; to utilize the assistance of the nursing staff during the hospitalization period; and to form specific plans for themselves and the infants after discharge) displayed more affectionate touch during interactions with their infants prior to discharge. Their infants, moreover, were more socially alert and less withdrawn (Keren, Feldman, Eidelman, Sirota, & Lester, 2003). Other research has shown that factors such as the parents' own adverse tactile experience as children and their satisfaction with the touch they experience as adults can influence the frequency with which they touch their preterm infant and the amount of affectionate touch they use (Weiss & Goebel, 2003). A mother's use of affectionate touch has been found to increase security of attachment among preterm infants and reduce their likelihood of developing emotional and behavioral problems as toddlers (Weiss, Wilson, Hertenstein, & Campos, 2000; Weiss, Wilson, St. Jonn Seed, & Paul, 2001).

Touch interventions for premature infants, in particular massage therapy, have been shown to improve the infant's state regulation and neuromaturation, reduce hospital stay, and accelerate motor development (Field, 1995). In a randomized control study of preterm massage, three groups were included: infants massaged by their mothers, infants massaged by trained nurses, and controls matched for demographic and medical conditions. While both massage groups showed a quicker weight gain (Ferber et al., 2002), mothers who massaged their own infants were more sensitive and provided more affectionate touch, and their infants showed higher social engagement during interactions at 3 months (Ferber & Feldman, 2005).

Maternal PPD. Although PPD does not preclude maternal-infant physical contact, depressed mothers appear to avoid physical proximity and provide minimal levels of affectionate touch. In every sample we have observed—that is, in newborns, infants, toddlers, preschoolers, school-aged children, and adolescents of various cultures, backgrounds, and risk conditions—maternal depressive symptoms were negatively related with the amount of affectionate touch mothers used during infancy; depressed mothers often did not sit within the child's proximity and at later ages stayed outside the child's reach. In terms of the neuroendocrine basis of bonding, mothers with high depressive symptoms showed lower OT levels both at the first trimester of pregnancy and in the postpartum, suggesting that physiological support systems that prepare mothers for the expression of maternal behavior may be disrupted in PPD (Feldman, Weller, et al., 2007). Assessing maternal brain activations, mothers who reported high depressive symptoms and low care from their own mothers during childhood showed reduced activation on fMRI in key parenting brain areas, findings which point to the crossgeneration transmission of maladaptive parenting and its effects on the neurobiology of parenting (Kim et al., 2010).

In a longitudinal study of maternal PPD, a community cohort of more than 2,000 women was recruited in the second postpartum day to complete measures of depression and anxiety. Of these women, those who were consistently depressed across the first year and were diagnosed as suffering from a major depressive disorder when the infant was 9 months old were compared with women who were diagnosed with anxiety disorders and with matched controls. Of the three groups, depressed mothers showed the lowest levels of sensitivity and lower levels of touch synchrony than other groups; their infants, in turn, showed high cortisol reactivity to stress (Feldman et al., 2009). These findings accord with animal literature which suggests that maternal contact, handling, and touch shape the infant's stress management systems throughout life (Weller & Feldman, 2003). Follow-up of this cohort at 5 years of age currently shows that depressed mothers have lower levels of OT and their husbands—consistent with the "endocrine fit" hypothesis between cohabitating couples—similarly had lower OT levels as compared to control mothers and fathers. During interactions with their infant, depressed mothers showed less warmth, affectionate touch, and reciprocal interactions; they also preferred to sit out of the child's reach, highlighting specific difficulties in the domain of physical intimacy among depressed mothers. Children of clinically depressed mothers at 5 years, in turn, demonstrated higher levels of behavior problems, lower neurocognitive skills, and diminished capacity for empathy.

Our work suggests that infants of depressed mothers tend to show highly withdrawn behavior, presenting similar difficulties with physical proximity and touch as those shown by their mothers. Such withdrawal could be an early risk indicator for the development of depression in children and for potential touch aversion. In a study assessing withdrawal behavior in infants referred to a community-based mental health clinic, it was found that referred infants received higher withdrawal scores than nonreferred infants matched for demographic conditions and that maternal depressive symptoms, combined with reduced maternal sensitivity and reciprocity, predicted a clinical diagnosis on the infant withdrawal scale (Dollberg, Feldman, Keren, & Gudeney, 2006). Such findings point to the links between an infant's tendency to avoid touch and the risk for future psychopathology.

Feeding disorders and failure to thrive. The associations between maternal deprivation and children's growth restriction and nonorganic failure to thrive have been proposed since the early work of Spitz (1946) with World War II orphans. We examined the specific links between touch patterns and feeding problems among three groups of 9- to 34-month-old infants: children diagnosed with feeding disorders, children diagnosed with other primary disorders, and case-matched controls. Patterns of maternal and child touch and physical proximity were microcoded. Mothers of children with feeding disorders provided lower levels of touch in all categories, including affectionate, proprioceptive, and unintentional touch, and positioned their children out of arms' reach. In parallel, children with feeding disorders displayed less affectionate touch, more negative touch, and more rejection of the mother's contact. These children were also more withdrawn during feeding and play interactions, and the feeding sessions were less efficacious and more chaotic; in addition, children were less able to complete the meal (Feldman, Keren, Gross-Rozval, & Tyano, 2004).

Similar results emerged from a 1-year follow-up on the precursors of feeding disorders among low-risk premature infants, who are at a higher risk for feeding difficulties than infants born at term. Mother–infant feeding and nonfeeding interactions were observed prior to discharge, and feeding difficulties were assessed at 1 year through maternal interview and feeding observations. Infants whose mothers provided more affectionate touch in the neonatal intensive care unit (NICU) were more engaged during feeding and less withdrawn at 1 year, and the feeding sessions were characterized by higher independence and more efficacy. These children also exhibited fewer feeding problems at 1 year (Silberstein et al., 2009).

Taken together, the findings presented in this section demonstrate that in humans, similar to other mammals, maternal affectionate touch and physical contact are essential components of the maternal repertoire during the first months of life and contribute to the consolidation of the maternal sensitive style and the infant's ultimate growth. The findings also suggest that maternal touch involves a distinct neurobiological system, expressed in specific brain circuitry, hormonal markers, and autonomic response. These systems support the development of a healthy bond between mother and child and are disrupted in cases of psychopathology. Better understanding of these biological underpinnings may help uncover specific risks to infant development under a variety of risk conditions and lead to the construction of more specific interventions.

MATERNAL PHYSICAL CONTACT IN INFANCY UNDER CONDITIONS OF MATERNAL SEPARATION: THE KC INTERVENTION AND ITS LONG-TERM OUTCOME

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Prematurity is a condition that involves both immaturity of physiological systems and maternal separation. Premature birth truncates the normal development of neurological systems that are responsible for the regulation of basic physiological processes, such as the biological clock, feeding, thermoregulation, stress management, attention, and social relationships (Feldman, 2004). Birth alters the developmental course of brain maturation and, since even the most optimal incubator conditions cannot mimic the intrauterine environment, delays the maturation of physiological regulators. As a result, premature infants often exhibit difficulties in the development of physiological and behavioral regulation in infancy. During later childhood and adolescence, children born prematurely often show higher levels of conduct disorders, more attention and hyperactivity problems, lower frustration tolerance, and poorer social skills (Allin et al., 2001; Malatesta, Grigoryev, Lamb, Albin, & Culver, 1986; McCormick, Workman-Daniels, & Brooks-Gunn, 1996; Ruff, 1986; Sigman, Cohen, Beckwith, & Parmelee, 1986; Thoman, Denenberg, Sievel, Zeidner, & Becker, 1981).

The KC Intervention

Similar to many other natural forms of therapy, the KC intervention emerged out of necessity. Confronted with a shortage of incubators in Bogota, Colombia, the medical staff used parents as natural incubators. Infants remained physically attached to the mother around the clock until they matured and were able to maintain their own body heat in the external environment, and fathers and other family members often participated in the KC intervention for parts of the day. A series of randomized clinical trials in Colombia showed that the "kangaroo mother intervention" was safe in caring for low birth-weight premature infants and did not increase mortality or morbidity rates as compared to infants cared for by standard incubator care (Charpak, Ruiz, de Calume, & Charpak, 1997; Sloan, Camacho, Rojas, & Stern, 1994). Over the last 15 years, the KC intervention has become a standard care option for parents in industrialized countries. Once the infants' medical condition stabilizes, infants are placed naked (wearing a diaper and sometimes a cap) on the parent's chest in the "kangaroo" position while still being attached to the monitoring devices. Parents are thus able to experience full body contact with their infant, an experience that improves their sense of efficacy and the bonding with the child (Affonso, Bosque, Wahlberg & Brady, 1993).

Most studies on the benefits of the KC intervention have assessed short-term outcomes measured during the hospitalization period, including an improvement in infant state, increase in nursing rates and maternal lactation, and improvement in the mother's mood and sense of parenting. However, authors have criticized these early studies on the basis of less-than-rigorous methodology, reliance on parental report, lack of observation of parent–infant interaction, and lack of longitudinal follow-up of the treated versus not treated infants (Charpak et al., 1997). Recently, however, several follow-up studies comparing infants receiving KC in the neonatal period with controls have been reported. Here, we describe our longitudinal research, which is among the most comprehensive follow-ups of the KC intervention. We suggest that, in addition to assessing the practical benefits of Kangaroo contact on preterm development, the KC intervention provides a unique experimental paradigm for addressing key theoretical issues in a human model. These issues include the short- and long-term effects of maternal separation, the positive impact of touch and contact on self-regulatory systems, the role of early experience in infant development, and the effects of minor variations in maternal bonding on later growth. Below we address these issues by looking at the impact of mother–infant contact on four domains: (1) infant self-regulation (infant arousal, attention, and emotion), (2) infant neuromaturation and physiological regulation, (3) maternal well-being and mood, and (4) parent–child relationships.

The Longitudinal KC Project: Long-Term Effects on Mother and Child

The Israeli longitudinal KC Project followed 146 low birth-weight premature infants and their families born in the Jerusalem and Tel-Aviv areas in Israel. All infants in the study were born with a birth weight below 1,750 g and a gestational age (GA) of 33 weeks or less to two-parent families of middle-class background. Seventy-three infants received KC for at least 1 hour per day for a period of at least 2 weeks and 73 cased-matched infants served as controls, matched for gender, birthweight, GA, degree of medical risk, and family demographic (including maternal and paternal age, education, and birth order). KC was provided by mothers, as fathers were not willing to commit to providing an hour a day for at least 14 consecutive days, which we required from mothers. No differences between groups were found on Apgar 1 and 5 scores, the ratio of vaginal to Cesarean delivery, and the family's social support network. The KC was targeted to a period when the infant was still incubated, and full maternal-infant bodily contact was precluded for medical reasons. Infants and their parents were seen at pre-kangaroo baseline (controls were observed at 32 weeks GA, matched to the mean age of KC initiation), at term age, and at 3 and 6 months corrected age. A subsample (*N* = 70) was observed at 12 and 24 months and at 5 years. Recently, we completed a comprehensive assessment of the majority of the sample (*N* = 115) at 10 years.

The pre-kangaroo and term observations took place in the hospital, the 3-month observation was conducted in the family home, and the 6-month assessment took place in a developmental laboratory, to allow for the assessment of infant behavior in different settings and contexts. The 1-, 2-, 5-, and 10-year assessments took place in a university laboratory. At 10 years, infants also received an actigraph that measured their sleep patterns over five consecutive nights. Multiple outcome measures were collected, including physiological measures; standard cognitive and neurocognitive tests; tests of attention and perception; mother–child, father–child, and family interactions in age-appropriate tasks and contexts; and parental interviews and self-reports. Overall, the findings demonstrate that the Kangaroo intervention has a beneficial multidimensional impact on child development that lasts across the first decade of life.

Infant self-regulation. Since the work of Hofer (1995) on maternal proximity, maternal physical contact has been shown to facilitate the development of regulatory functions in animal models. The earlier studies in Bogota, Colombia, first noted that the Kangaroo method had a stabilizing effect on the infant's physiological systems (Fischer, Sontheimer, Scheffer, Bauer, & Linderkamp, 1998; Ludington & Golant, 1993), contributed to thermoregulation, and improved oxygenation (Acolet, Sleath, & Whitelaw, 1989; Bauer, Sontheimer, Fischer, & Linderkamp, 1996; Bier et al., 1996; Bosque, Brady, Affonso, & Wahlberg, 1995; Fohe, Dropf, & Avenarius, 2000; Ludington-Hoe & Swinth, 1996; Tornhage, Stude, Lindberg, & Serenius, 1998). Similarly, KC reduced infant crying (Michelsson, Christenson, Rothganger, & Winberg, 1996) and beta-endorphin levels (Mooncey, Giannakoulopoulos, Glober, Acolet, & Modi, 1997), pointing to the effects of KC on attenuating the stress response. KC has also been shown to contribute to state regulation, increasing both quiet sleep (Gale, Frank, & Lund, 1993) and alert states (Gale & Vandenberg, 1998), and to improve growth rates (Kambarami, Chidede, & Kowo, 1998)—findings that highlight the positive impact of skin-to-skin contact on growth and maturation. A review summing 25 years since the introduction of the Kangaroo Mother Intervention showed that, overall, the intervention was not only safe but helped improve the infant's regulatory capacities in the neonatal period and had a positive impact on the mother–infant and family relationship in later infancy (Charpak et al., 2005).

In light of the role of maternal contact in organizing the biological clock, we examined sleep-wake cyclicity patterns in the KC and control infants. Four hours of infant state were observed at pre-kangaroo and again at term age. As the sleep-wake cycle of newborns lasts between 60 and 70 minutes, this period enabled the detection of several sleep-wake cycles. States were defined according to Brazelton (1973) and included quiet sleep, active sleep, sleep-wake transition, unfocused alertness, alert wakefulness, and cry. A coder sat at the infant's bedside and marked infant state for each 10-second epoch. The distribution of states across the 4-hour period was examined and sleep-wake cyclicity was measured with spectral analysis, with higher amplitudes indicating better organization of the biological clock. No differences were found at the pre-kangaroo observation. At term age, infants who received KC showed longer periods of quiet sleep and alert wakefulness and shorter periods of active sleep; their sleep-wake cycle was also more organized. The consolidation of the sleep-wake cycle is required for the later fine-tuning of the arousal system and its regulation into micopatterns of activity and rest, observed in tasks such as attention shifting, arousal modulation, and attention maintenance (Feldman, Weller, Sirota, & Eidelman, 2002). As suggested, more organized sleep-wake cyclicity indicates a more mature balance between the reactive and regulatory aspects of the state system, which provides the global framework for experience, growth, and learning in the neonatal period (Brazelton, 1990).

At 3 months corrected age, infants' arousal modulation and emotion regulation was assessed as follows: infants were presented with 17 stimuli that increased in the magnitude of intrusiveness from a simple unimodel stimulus (light, soft sound) to multimodal, high-impact stimuli (a car flashing lights and making loud noises approaching the infant). Each stimulus was presented for 10 seconds with a 20-second break between stimuli. Infants who received skin-to-skin contact showed a higher "threshold" to negative emotionality and they were able to tolerate more aversive stimuli before crying. Similarly, the KC infants showed a better modulation of arousal to stimulus onset and offset. The ability to shift between optimal reactivity during information intake and to utilize the period of stimulus offset for rest and processing is an index of an efficient, task-specific and mature information processing system (Feldman & Mayes, 1999); findings suggest that KC impacted the infants' emotion regulation and arousal modulation capacities. The findings also highlight the role of maternal proximity in forming a barrier to outside stimulation and for increasing the threshold to negative reactivity, central components of the infant's emotion regulation capacities (Feldman, Weller, et al., 2002).

At 6 months corrected age, infant's exploratory behavior was assessed during a mother–infant exploration session. Infants in the KC group showed more sustained exploration, spent more time jointly manipulating the toy with their mother, and had longer periods of shared attention in which mother and child jointly attended to the toy (Feldman, Weller, et al., 2002).

The capacities to engage in sustained exploration and to enter into a process of shared attention precede the development of social–cognitive abilities that emerge toward the end of the first year.

At 1 year, infants who received KC were better able to manage separation distress. At the end of the visit, mothers were asked to leave the room and the infant remained with a stranger for several minutes. The child's behavior, affect, distress, and ability to maintain exploration were microcoded. Continuous with these infants' capacity to tolerate more distress at 3 months, KC infants showed less distress and were better able to maintain exploration of the environment during maternal absence.

Similar long-term effects were noted at 2 and 5 years. At 2 years, infants in the Kangaroo group showed better executive functions, measured with a delayed-response paradigm that taps the child's ability to suppress a dominant response after a delay. At 5 years, KC children showed better performance on the NEPSY, a neurocognitive test of executive functions that examines auditory and visual processing, and behavioral control.

Preliminary results from the 10-year assessment of 115 children are consistent with the findings across infancy and childhood. At both 5 and 10 years, general IQ no longer distinguished the group as it did across the first 2 years of life. However, the NEPSY test of executive capacities showed group differences at both 5 and 10 years, suggesting that as children grow, the benefits of early maternal contact become more specifically linked with regulatory skills and less with general intelligence. Possibly, the early differences between groups were influenced by the benefits to attention and frustration tolerance that are much more related to indices of mental development in infancy than in later years.

Infant neuromaturation and physiological regulation. The developmental theory of Gottlieb (1991) suggests that sensory development occurs sequentially, and during the first postnatal period, infants should receive significantly more stimulation to the primary senses—touch and proprioception—than to the secondary senses—vision and audition. Typical Western NICU conditions, however, reverse this order and bombard infants with continuous light and nonstop noise, which their immature systems cannot ward off (Als, 1991). Animal research has indicated that such conditions carry irreversible effects on neuromaturation, including permanent damage to the biological clock and information-processing capacities (Hao & Rivkees, 1999; Sleigh & Lickliter, 1998). Exposure to excessive pain also results in permanent structural and functional disruptions to brain maturation (Grunau, 2002).

Interestingly, intervention programs that attempt to address lack of appropriate stimulation, such as massage, rhythmic stimulation, or minimal handling to filter overwhelming stimulation, improve neuromaturation in terms of physical growth, motor maturity, and physiological organization in premature infants (Feldman & Eidelman, 1998). Thus, providing components of the maternal presence during a sensitive period for neurodevelopment (Schore, 2001; Tucker, 1992) and brain–behavior relationships can have a lasting impact on the physiological support systems that modulate arousal and manage stress throughout life (Laviola & Terranova, 1998). Indeed, Ludington-Hoe and Swinth (1996) suggested that skin-to-skin contact contributes to maturation in each of the five neurobehavioral systems that are compromised by premature birth, including autonomic, motor, state, attention–interaction, and self-regulation. KC also appears to buffer the experience of pain by functioning as an analgesic during painful medical procedures (Gray, Watt, & Blass, 2000) and assists in recovery after heart surgery (Gazzolo, Masetti, & Meli, 2000).

Several physiological systems that index neuromaturation, such as better stress reactivity and improved arousal regulation, were tested in our longitudinal study. The effect of KC on the maturation of the autonomic nervous system was operationalized by cardiac vagal tone (Porges, 1996), which has been used as a physiological marker of the infant's emotion regulation capacities. In premature infants, lower vagal tone is observed due to the immaturity of neurological systems. Vagal tone has also been associated with the degree of medical risk (DiPietro & Porges, 1991) and the resting vagal tone at term age was found to predict infant development up to 6 years of age (Doussard-Roosevelt, McClenny, & Porges, 2001). Thus, it is clear that interventions that can impact on the maturation of vagal tone are likely to have an important impact on the infant's neurodevelopmental maturation.

We measured vagal tone at pre-kangaroo baseline and at 37 weeks GA. The vagal tone index was extracted from 10 minutes of ECG recording according to a system developed by Porges. Although vagal maturation during this period was observed for all infants, those receiving KC showed a higher vagal tone at 37 weeks GA, indicating a quicker maturation of the autonomic nervous system (Feldman & Eidelman, 2003a). The findings suggest that kangaroo contact accelerates the neuromaturation rate during a period of rapid brain development as measured by objective physiological indices. Such findings point to the pervasive impact of maternal contact during periods of early separation.

Resting vagal tone in the neonatal period appears to shape the development of self-regulatory capacities throughout childhood (Feldman, 2009). We found that neonatal vagal tone was related to emotion regulation in the first year, attention regulation in the second year, and self-regulation skills at age five, including the capacity for self-restraint, lower levels of externalizing and internalizing symptoms, and better executive control. At 10 years, we measured vagal tone again in response to an emotional (inter-adult anger) and cognitive challenge. Consistent with previous research (El-Sheik, 2001) and with the findings demonstrated for maternal touch in infancy (Feldman, Singer, et al., 2010), children who received KC in infancy showed more optimal functioning of the autonomic nervous system, as observed in higher baseline vagal tone and a larger vagal brake in response to challenge.

Neuromaturation in the neonatal period was also tested with the Neonatal Behavior Assessment Scale (Brazelton, 1973). Following KC, infants scored higher on the orientation and habituation clusters. Poor orientation has been associated with stress reactivity and negative emotionality (Auerbach et al., 1999; Spangler & Scheubeck, 1993) and disrupted habituation is observed in conditions such as prenatal exposure to cocaine (Mayes, Granger, Frank, Schottenfeld, & Bornstein, 1993). Our findings are consistent with a Japanese study which showed higher orientation following KC (Ohgi et al., 2002). These findings point to the role of maternal contact in organizing infant orientation to the environment, possibly leading to more mature neurodevelopmental profiles throughout childhood.

Two other physiological systems were assessed at 10 years—sleep quality using actigraphs and functioning of the hypthalamic-pituitary-adrenal axis indexed by cortisol baseline and reactivity. At 10 years, the sleep of infants who received KC in infancy was less disrupted: there were fewer bouts of wakefulness, each bout lasted for a shorter duration, and the latency to falling asleep was quicker. In terms of cortisol reactivity, early maternal contact decreased the magnitude of the stress response and afforded quicker return to baseline, the two components of resilience.

The 10-year longitudinal results suggest that, similar to mammals, early maternal contact has a lifelong effect on physiological regulation and stress management systems. It is possible that the amazing long-term effects of a relatively short, inexpensive intervention relate to the immediate effects of the Kangaroo intervention on organizing the autonomic response, the stress management system, and the biological clock. Better organization of these systems during the early sensitive period possibly sets the trajectory of infant development on a more optimal path that continues in the same way across development.

Maternal well-being and mood. In addition to improving the infant's condition, KC has been shown to improve the mother's well-being and depression following premature birth. Dombrowski, Anderson, Santori, and Burkhammer (2001) have applied the KC intervention successfully with women who suffered PPD, based on the idea that physical contact has been associated with more positive maternal feeling toward the infant. KC mothers have reported more positive feelings toward their infants, lower parental stress, and better sense of the parenting role (Affonso et al., 1993; Neu, 1999). It was suggested that KC may help reverse some of the negative effects of premature birth on the mother, such as her identity as a competent parent, and the guilt and anxiety that typically accompany premature birth (Brooten et al., 1988). In addition, KC was found to contribute to maternal well-being in developing countries. Reports from Zimbabwe (Kambarami, Chidede, & Kowo, 1999) and Papua New Guinea (McMaster & Vince, 2000), among others, describe the positive effects of KC on maternal and infant well-being. These findings highlight the KC intervention as a natural, cost-free intervention, which does not require long training or sophisticated methodologies but carries a significant benefit to the infant and the mother–infant dyad.

In our research, similar effects of kangaroo contact on maternal mood were observed. Upon discharge, maternal PPD was lower among KC mothers, and an interaction effect of group and medical risk indicated that KC improved maternal mood to a greater extent among those with low-risk premature infants, who were able to provide KC in the few days after birth (Feldman, Eidelman, Sirota, & Weller, 2002). At term age, mothers also perceived their infants as less different than the average full-term neonate, and at 6 months KC mothers reported lower separation anxiety. These findings are significant since mothers of premature infants often suffer higher levels of anxiety and depression (Brooten et al., 1988) and perceive their infant as very different from the normal healthy child (Levy-Shiff, Sharir, & Mogilner, 1989). Thus, it appears that KC mothers were better prepared for the maternal role.

However, by ages 1, 2, and 5 years, no differences in maternal mood, a sense of well-being, parenting stress, or efficacy in the parenting role were observed among our groups. Similarly, we found no differences from the recent follow-up at 10 years. However, since PPD was associated with lower levels of mother–infant reciprocity, lower maternal touch, and reduced sensitivity across the first 10 years and because PPD exerts a long-term negative effect on children's cognitive, social, and emotional growth (Goodman & Gotlib, 1999), the improvement in the mother's postpartum mood following KC may have had an indirect effect on the child's social development and the ongoing mother–child relationship.

Parent–child relationships. Premature birth disrupts the development of maternal-infant bonding for reasons related to both maternal separation and infant dysregulation. Premature infants have difficulties maintaining visual attention during play (Eckerman, Hsu, Molitor, Leung, & Goldstein, 1999) and their emotional expressions are often unclear (Malatesta et al., 1986), making it harder for mothers to read the child's social signals. Preterm infants are also prone to negative emotionality and less able to modulate arousal, making the interactions less rewarding to the parent.

In our longitudinal study, mother–child interactions were conducted at every assessment and often involved several tasks and contexts. At the 3-month assessment, we conducted a home visit and observed father–infant and family interactions as well.

Upon discharge, mother–infant interactions were observed in the NICU and microcoded for the maternal behavior constellation. As expected, KC had its most notable effect on the mother's touch patterns, with mothers in the KC group showing more affectionate touch to their infants. Mothers were also more adaptive to infant signals and the infants were more alert during social interactions (Feldman, Eidelman, et al., 2002), indicating that the mother–infant dyad was off to a better start following the KC intervention.

At the 3- and 6-month assessments, more positive interactions between KC mothers and their infants continued. Global coding of mother–infant interactions with the CIB (Feldman, 1998) revealed that KC mothers were more sensitive and less intrusive, that infants were more socially engaged and less negative, and that the level of dyadic reciprocity between mother and child was higher compared to controls (Feldman, Weller, Eidelman, & Sirota, 2003). The improvements in relational pattern were observed on the dimensions that were reported as compromised by premature birth, such as reduced maternal sensitivity and intrusiveness, lower maternal-child reciprocity, and lower infant involvement. These more optimal interactions at 3 and 6 months predicted higher scores on the Mental Development Index of the Bayley Scales of Infant Development (Bayley, 1993) at 6, 12, and 24 months among the KC infants.

At 1 and 2 years, toddlers who received KC were more involved and socially alert during interactions, and the dyadic interactions were more reciprocal. These findings point to a persistent effect of early contact on better behavior organization and socialization across infancy. Significant findings on the same factors emerged at the 10-year assessment. At 10 years, children engaged in two interactions with their mothers that were coded with the childhood version of the CIB. The first was a positive interaction in which parent and child planned a "fun day" together and the second was a conflict interaction. Children who received KC in infancy showed higher social engagement, and the reciprocity between mother and child was higher.

These long-term findings suggest that early Kangaroo contact has lasting impact on children's social–emotional development and their capacity to engage in a synchronous relationship with their mother. The effects may be due to the fact that mother and child continue to mutually influence each other across development. Thus, a more socially responsive child elicits more synchronous interactions, and mother–child reciprocity, in turn, contributes to the development of child social engagement.

At 3 months, we also assessed father–child and family interaction patterns at a home visit. Father–child interactions in the KC group were more optimal in terms of higher paternal sensitivity, lower paternal intrusiveness, and higher father–child reciprocity. Although fathers did not engage in KC, the increase in infant regulation and sociability following KC may have contributed to the father's sensitive involvement. It is also possible that fathers adopted the more sensitive interaction of the Kangaroo mothers (Feldman, Weller, et al., 2003). Although the mechanisms for this improvement are not fully understood, a more positive atmosphere between mother and child may facilitate a better home atmosphere and more optimal fathering.

Triadic interactions between mother, father, and child were conducted at 3 months and microcoded for gaze and affect of each family member, proximity position between each two members, and touch patterns between each two family members (mother–infant, father–infant, and mother–father). The family atmosphere as a whole was globally coded on the dimension of coherence (the level of harmony, reciprocity, and unity in the triad) and intrusiveness (the degree to which members interfered with each other's communications). Families in the Kangaroo groups showed better functioning on both the microanalytic and global assessments. KC infants showed lower levels of gaze aversion and less negative affect, and both mothers and fathers affectionately touched their infants more often during triadic interactions. In addition, triadic interactions of KC families were described as more harmonious and less intrusive. Family processes, which are dynamic and multidimensional, are sensitive to changes in each family member, and these individual changes lead to better organization, harmony, and coherence in the triad following intervention (Fivas-Depeursinge & Corboz-Warnery, 1999). Thus, KC seems to have an impact on a large array of developmental processes, which extend beyond the mother–infant dyad and much beyond the neonatal period. The early improvements in infant self-regulation and in early mothering carry a positive effect on fathering and family processes, as well as the child's later cognition, learning, and social adaptation.

CONCLUSION

Touch and contact are the primary components of every loving relationship. Receiving touch and contact immediately after birth help the human infant organize orientation to the social world and function adaptively within society. Human mothers, similar to other mammalian mothers, are genetically programmed to provide the species-typical form of affectionate touch and physical contact to their infants immediately after birth. Such patterns of touch and contact are supported by specific physiological systems that include genetic, hormonal, and brain markers. Prematurity provides a natural experiment in assessing the effects of structured maternal-infant contact during a period of early and persistent maternal deprivation, on the infant's physiological maturation, regulatory function, and social relationships. The lasting effects of early skin-to-skin contact on the functioning of a variety of physiological and social systems across the first decade of life indicate that the provision of touch and proximity during this sensitive early period may have a lifelong impact on the infant's self-regulation, social relatedness, and capacity to handle stress and frustration. The provision of early contact also enables children to develop reciprocal relationships with their attachment partners and, consistent with the findings for OT in animals, to hopefully engage in loving relationships with their partners and provide more optimal parenting in the next generation.

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