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Skin-to-Skin Contact (Kangaroo Care) Promotes Self-Regulation in Premature Infants: Sleep–Wake Cyclicity, Arousal Modulation, and Sustained Exploration

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The effect of mother–infant skin-to-skin contact (kangaroo care, or KC) on self-regulatory processes of premature infants was studied. Seventy-three infants who received KC were compared with 73 infants matched for birth weight, gestational age, medical risk, and family demographics. State organization was measured in 10-s epochs over 4 hr before KC and again at term. No differences between KC infants and controls were found before KC. At term, KC infants showed more mature state distribution and more organized sleep–wake cyclicity. At 3 months, KC infants had higher thresholds to negative emotionality and more efficient arousal modulation while attending to increasingly complex stimuli. At 6 months, longer duration of and shorter latencies to mother–infant shared attention and infant sustained exploration in a toy session were found for KC infants. The results underscore the importance of maternal body contact for infants' physiological, emotional, and cognitive regulatory capacities.

Premature birth deprives the infant not only of the protective and nurturing environment of the mother's womb but also of the benefits of maternal proximity and contact. Prematurity thus creates a unique phase in the life of the human infant, a period in which portions of the newborn's prenatal development take place in an extrauterine environment under conditions of maternal separation. Although the effects of prematurity on the physiology and behavior of the developing child have been frequently studied, far less research has examined the associations between intervention applied in the neonatal period and developmental consequences. Most studies on the long-term effects of intervention for premature infants have shown either general gains in infants' cognitive abilities or a global increase in maternal sensitivity (Als et al., 1994; Bernard & Bee, 1983; Resnick, Eyler, Nelson, Eitzman, & Bucciarelli, 1987; Scarr-Salapatek & Williams, 1973; Solkoff, Yaffe, Weintraub, & Blase, 1969). Such global findings, however, provide limited understanding of the mechanisms that link intervention to specific outcomes.

This study examined the effects of mother–infant skin-to-skin contact in the neonatal period on the development of self-regulatory skills in premature infants. Specifically, we examined the effects of such contact on the infant's capacities to regulate sleep and wake states, organize behavior, regulate negative emotions, modulate arousal, coordinate attention to mother and an object, and sustain effortful exploration of the environment. Skin-to-skin contact was expected to modify each of the adverse conditions associated with the prematurity state, that is, maternal separation, stimulus overload caused by routine nursery care, sensory deprivation resulting from limited tactile and maternal contact during the incubation period, and pain exposure (Als et al., 1994; Feldman & Eidelman, 1998; White-Traut & Nelson, 1988). We hypothesized that skin-to-skin contact would promote physiological and behavior organization as expressed in more mature state organization in the neonatal period and in improved emotion regulation, joint engagement, and exploratory skills in the first half-year.

Three theoretical perspectives guided the study's hypotheses. The first considers the effect of timing on behavior disorganization and postulates that there are unique time windows in which certain inputs are required for optimal development of the central nervous system. Because of the special sensitivity of the organism to the required input at that period, minor interventions may exert significant long-lasting impact (Cicchetti & Cohen, 1995; Schore, 1996; Tucker, 1992). Animal studies indicate that the first post-birth period constitutes a sensitive period for maternal contact and

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that maternal separation has a negative and irreversible effect on the arousal system (Laviola & Terranova, 1998). In human and animal models, tactile stimulation during periods of early maternal separation was found to improve state organization, stress reactivity, physiological maturation, and attention (Field, 1995; Lehmann, Stohr, & Feldon, 2000; Scafidi et al., 1990; Wigger & Neumann, 1999).

The second perspective is Gottlieb's (1976, 1991) theory of the ontogeny of sensory development. Gottlieb contended that sensory development occurs in a sequential order and that the primary senses of touch and proprioception precede the secondary senses of vision and audition. As such, premature birth and the ensuing routines of nursery care reverse this developmental sequence, because hospital nursery conditions bombard the infant's auditory and visual systems while providing minimal tactile and proprioceptive stimulation. Simulating the continuous lights and sounds of a typical hospital nursery and exposing newborn animals to these conditions resulted in permanent damage to the biological clock, deformed sensory processing, and immature habituation in the young animal (Hao & Rivkees, 1999; Philbin, Ballweg, & Gray, 1994; Sleigh & Lickliter, 1998), confirming the potentially damaging effects of hospital nursery conditions on the developing infant.

The third perspective emphasizes the role of maternal proximity in organizing the rhythms of activity and rest and in facilitating behavior inhibition (Sander, 1984, 1987). Hofer (1973, 1984, 1995) noted that maternal proximity provides a set of biobehavioral regulators for the infant's physiology and behavior that function to regulate activity and rest in various systems. Organization of the biological clock is considered to provide the foundation for smaller scale behavioral rhythms, such as the cycles of arousal and attention observed during information processing or face-to-face interactions (Winfree, 1980; Wolff, 1967, 1987; Wright & Harding, 1992). Such microrhythms play an important role in the development of information processing, self-regulation, and cognitive skills (Feldman, Greenbaum, & Yirmiya, 1999; Feldman & Mayes, 1999). Premature infants tend to show disturbed rhythms of activity and rest (Holditch-Davis, 1990; Lester, Hoffman, & Brazelton, 1985), which may be partially due to the deprivation of maternal proximity. In synthesizing these three perspectives, it may be postulated that structured maternal–infant skin-to-skin contact during the neonatal period may exert a lasting impact on self-regulation by providing appropriate tactile and proprioceptive stimulation while buffering the effects of excessive visual and auditory stimuli.

Among the systems most injured by premature birth is the arousal system and its capacity to self-regulate. Preterm infants exhibit difficulties in organizing attention, regulating negative affect, maintaining optimal thresholds of reactivity, moderating social interactions, and sustaining exploration of the environment (Greene, Fox, & Lewis, 1983; Malatesta, Grigoryev, Lamb, Albin, & Culver, 1986; Ruff, 1986; Sigman, Cohen, Beckwith, & Parmelee, 1986; Thoman & Graham, 1986). Moreover, physiological and behavior regulation in premature infants has been found to predict cognitive development. Vagal regulation (Doussard-Roosevelt, Porges, Scanlon, Alemi, & Scanlon, 1997), state organization (Beckwith & Parmelee, 1986), attention shifting (Sigman, Cohen, & Beckwith, 1997), and cyclicity of arousal during mother–infant interaction (Feldman, Greenbaum, Yirmiya, & Mayes, 1996) predicted cognitive skills in later childhood and adolescence. Such findings point to the link between the regulation of arousal in infancy and the development of cognitive competencies.

Animal models of maternal separation provide evidence on the relations between maternal separation, arousal disregulation, and behavior disorganization. Anand and Scalzo (2000) described two pathways by which prematurity disrupts behavior organization. Maternal separation leads to apoptosis (programmed cell death) in multiple areas of the immature brain, and pain exposure causes excessive excitatory amino acid activation, resulting in excitotoxic damage to developing neurons. Behaviorally, both conditions are expressed in disturbed reactivity, difficulties in sustained attention, and inability to self-regulate. Rodents separated from their mothers showed changes in the prelimbic prefrontal areas, which caused increased excitation and hyper-reactivity (Poeggel et al., 1999). Furthermore, intervention that provides separate components of the maternal proximity complex, such as touch, smell, or body heat, during the postnatal period may be sufficient to induce lasting improvement in self-regulation (Laviola & Terranova, 1998). Weizman et al. (1999) found increased exploratory behaviors in handled rats, better regulation of the hypothalamic-pituitary-adrenal (HPA) axis, improved functioning of the renin-angiotensin system—the system implicated in attention and memory processes as well as in sleep–wake cyclicity (Wright & Harding, 1992)—and better autonomic regulation. Maternal contact led to persistent improvement in HPA regulation in rats (Stanton, Wallstrom, & Levine, 1987). Similar results were found in premature infants, who showed improved state organization, habituation, and motor control following tactile stimulation (Field, 1995; Scafidi et al., 1990).

Mother–infant skin-to-skin contact, commonly known as kangaroo care (KC), is a method that was first used in Bogota, Colombia as an alternative to incubator care. Premature infants whose medical condition stabilized were placed naked between their mothers' breasts, to facilitate nursing, while body temperature was regulated by their mothers' body heat. Full body contact was maintained until the infants matured (Whitelaw & Sleath, 1985). In a series of randomized clinical trials, KC was found safe in comparison to standard incubator care (Charpak, Ruiz, de Calume, & Charpak, 1997; Sloan, Camacho, Rojas, & Maternidad Isidro Ayora Study Team, 1994). Recently, the KC method has spread to industrialized countries, where parents and infants use the kangaroo position for part of the day to promote bonding (Anderson, 1991; Ludington-Hoe & Swinth, 1996). Although few longitudinal data are available, mothers who provided KC reported more positive feelings toward the infant, lower parental stress, and a better sense of the parenting role (Affonso, Bosque, Wahlberg, & Brady, 1993; Bier et al., 1996; Neu, 1999).

Skin-to-skin contact was found to have a stabilizing effect on the physiology and behavior of the premature infant (Fischer, Sontheimer, Scheffer, Bauer, & Linderkamp, 1998). During contact, infants spent more time in quiet sleep, heart rate was lower and more stable, apnea and bradycardia decreased, body temperature was maintained, and oxygenation improved. Infants treated with KC were discharged earlier from the hospital, which points to the positive effect of skin-to-skin contact on physiological maturation (Acolet, Sleath, & Whitelaw, 1989; Bauer et al., 1997; Bosque, Brady, Affonso, & Wahlberg, 1995; Ludington, 1990;

Ludington-Hoe, Hashemi, Argote, Medellin, & Rey, 1992; Messmer et al., 1997; Richardson, 1997; Whitelaw, 1990). Kangaroo contact was found to improve arousal regulation and stress reactivity. Michelsson, Christenson, Rothganger, and Winberg (1996) found that infants in cots cried 10 times as much as infants receiving such contact, and spectographic cry analysis showed their cries to be more distressful. Skin-to-skin contact had an analgesic effect during and following painful medical procedures (Gazzolo, Masetti, & Meli, 2000; Gray, Watt, & Blass, 2000), and a significant reduction in beta-endorphin was observed after KC, which suggests an attenuation of the stress response (Mooncey, Giannakoulopoulos, Glober, Acolet, & Modi, 1997). These findings strongly support the concept that skin-to-skin contact organizes the infant's physiology, facilitates the maturation process, and helps reduce negative emotionality.

The effects of skin-to-skin contact appear to persist after contact is ended. Following KC, premature infants slept longer and sleep was more restful and organized (Gale, Frank, & Lund, 1993). It is interesting that KC improved not only sleep states but also infant alertness, as shown by the findings that infants spent longer periods in alert states after receiving KC (Gale & Vandenberg, 1998). It is thus possible that KC organizes the biological clock by increasing the time infants spend in the two ends of the arousal continuum—quiet sleep and alert wakefulness—while reducing transitory states and active sleep. Skin-to-skin contact contributed to the regulation of negative arousal, and infants treated with KC were reported by their mothers to cry less compared with controls at 6 months of age (Whitelaw, Heiserkamp, Sleath, Acolet, & Richards, 1988). Unfortunately, most studies on the KC method were conducted with small samples, suffer methodological flaws, and present minimal longitudinal data, all of which emphasize the need for systematic investigation of the long-term consequences of skin-to-skin contact on infant development (Charpak, Ruiz-Palaez, & de Calume, 1996).

In this study, we examined the effects of skin-to-skin contact in the neonatal period on the emergence of regulatory processes in premature infants. We expected that skin-to-skin contact would have an organizing effect on the biological clock and that infants treated with KC would show more organized sleep–wake cyclicity. At 3 months, infants treated with KC were expected to show better regulation of negative emotions and better modulation of arousal in accordance with environmental demands. At 6 months, KC infants were expected to be more adept in coordinating attention to the mother and to objects during joint play and more skillful in the exploration of new toys, owing to the effects of maternal proximity on exploratory behavior. Because the capacity to sustain attention while exploring objects at this age was found to be a central predictor of cognitive competence in premature infants (Kopp & Vaughn, 1982), the contribution of early maternal proximity to attention processes (Hofer, 1973, 1984) was of particular interest. Similarly, given the suggestion that the biological clock provides the foundation for arousal modulation, emotion regulation, and attention (Dahl, 1996; Sander, 1984; Stratton, 1982; Wright & Harding, 1992), we hypothesized that sleep–wake cyclicity at term would be associated with the infant's capacity to regulate negative emotions, modulate arousal, and sustain exploration of the environment in the first months of life.

Method

Participants

Participants were 146 premature infants whose mean birth weight was 1,270 g (*SD* = 343.49; range = 530–1,720 g) and whose mean gestational age was 30.65 weeks (*SD* = 2.76; range = 24–34 weeks). Of these, 73 infants underwent KC, and 73 served as controls. Infants in the two groups were matched for gender, birth weight, gestational age, and medical risk. Infants were excluded from the study if they had a Grade III or IV intraventricular hemorrhage or suffered from perinatal asphyxia or metabolic or genetic disease. In the two study groups, all mothers were married to the infants' fathers, parents had at least a high school education, mothers were at least 20 years old, and all families were considered middle class by Israeli standards (Harlap, Davis, Grower, & Prywes, 1977). Families were matched for maternal age, education, parity (firstborn vs. laterborn), and maternal employment (no, part-, or full-time employment). Twins and singletons, equally numbered in the two groups, were matched separately for birth weight, gestational age, and medical risk. Family demographics and infant medical information for the two groups appear in Table 1. The group (KC vs. control) by multiple status (singletons vs. twins) by medical risk (high vs. low) matrix revealed no significant effects, indicating that twins and singletons in the two groups were evenly distributed among the higher and lower risk groups (all chi-squares were nonsignificant).

Because KC is a standardized care option in some hospitals in Israel and is not considered an experimental technique, prospective randomization of KC and control infants was precluded for ethical reasons. Comparisons were therefore made between matched infants born in two separate hospitals who were cared for concurrently. This method of recruitment minimized the selection bias that would have occurred if the comparison was between infants cared for in the same hospital whose mothers chose KC and whose mothers did not. The nurseries in the two hospitals are Level 3 referral centers with comparable numbers of admissions, case mixes, and nurse–patient ratios. In both units, parents have unlimited privileges and are encouraged to actively participate in infant care routines. There were no significant differences in the level of parental involvement (e.g., frequency and length of visits, care-taking activities) between the two sites.

Seventy-three control infants and mothers were enrolled in the study from Shaare-Zedek Medical Center (Hospital A), and 53 infants and mothers who received KC were enrolled from Schneider Children's Hospital (Hospital B). Subsequently, after KC was instituted in Hospital A, an additional 20 infants from Hospital A were enrolled in the KC group. There were no differences in birth weight, gestational age, and family demographics in the two subgroups of KC infants born in the two hospitals. To address the potential confounding effect of hospital site on the findings, we present information on all study variables for the three groups separately

Table 1
Family Demographic and Infant Medical Variables

	Kangaroo care		Control	
Variable	*M*	*SD*	*M*	*SD*
Birth weight (grams)	1,245.85	328.21	1,289.87	358.08
GA (weeks)	30.38	2.50	30.82	2.98
CRIB (medical risk score)	2.29	2.98	2.25	2.96
Mother's age (years)	29.63	4.72	29.07	6.14
Mother's education (years)	14.70	1.94	14.11	2.32
Father's age (years)	32.29	5.89	32.46	7.75
Father's education (years)	14.47	2.27	14.55	3.78
Male/female ratio	37/36		38/35	

Note. GA = gestational age; CRIB = Clinical Risk Index for Babies.

(KC—Hospital A, KC—Hospital B, and controls) in the Appendix, including post hoc comparisons between the groups.

Procedure

Infants were enrolled in the KC group when their medical situations stabilized and they were no longer being ventilated. Infants receiving supplementary oxygen by nasal catheter and/or intravenous fluids were enrolled in the study. Mother–infant dyads were enrolled in the study if the following three conditions were met: (a) mothers agreed to perform KC for at least 14 consecutive days; (b) on these days, mothers agreed to perform KC for at least 1 hr daily; and (c) infants were not expected to be transferred from enclosed incubators to open incubators during the 2-week periods. Thus, the KC intervention was targeted to a period when the premature infant would otherwise be deprived of full maternal contact. Mothers were trained by the nursing staff to perform KC. Infants were taken out of the incubator, were undressed (except for a diaper and sometimes a cap), and were placed between their mothers' breasts. During KC, infants remained attached to a cardio-respiratory monitor and were observed by the nursing team, who recorded the exact time mothers and infants remained in skin-to-skin contact and when the infants were returned to standard incubator care. During the study period, mothers provided an average of 26.62 hr of KC ($SD = 12.14$).

Infants and their mothers were observed and tested at four time points: before the initiation of KC (1–2 days), at term (37 weeks gestation), at 3 months corrected age, and at 6 months corrected age. For the control group, the pre-KC observation took place at 32 weeks gestation, matched to the mean age of the initiation of KC. The pre-KC and term assessments took place in the hospital, the 3-month assessment was conducted at the family's home, and the 6-month assessment was conducted at the laboratory. Twelve infants missed the 3-month visit, and 13 infants missed the 6-month visit. These infants and families did not differ from the remaining participants on any demographic or infant variables. In this report, we consider three sets of variables pertaining to self-regulation: state organization at the pre-KC assessment and at term; emotion regulation, reactivity, and arousal modulation at 3 months; and mother–infant shared attention and infant sustained exploration at 6 months.

State Observation at 32 Weeks Gestation and at Term Age

During 4 consecutive evening hours, trained coders observed the infant's state in 10-s epochs and entered the data into a computerized program. Because sleep cycles last approximately 60–70 min in term infants (Curzi-Dascalova, Peirano, & Inserm, 1988; Stern, Parmelee, & Harris, 1973), observations were made for 4 hours in order to enable the detection of several sleep–wake cycles. States were modeled after those described by Brazelton (1973) and Holditch-Davis (1990) and were defined as follows: *quiet sleep*—infant's eyes are closed, breathing is regular, and motor activity is minimal; *active sleep*—infant's eyes are closed, respiration is irregular, and motor activity and rapid eye movement occur sporadically; *sleep–wake transition*—eyes are typically closed but may open occasionally, motor activity is typical, and behaviors of both sleep and wakefulness are observed; *unfocused wakefulness*—eyes are typically open but may occasionally close, and motor activity is typically high; *alert wakefulness*—eyes are open and scanning, and motor activity is medium-range; *fuss/cry*—eyes are typically open, motor activity is typical, and the infant emits clear fuss vocalizations or a full cry. Observations took place between feedings, and arrangements were made to diminish interruptions during the observation period. In cases when interruptions occurred, the observation was terminated and was resumed when the infant returned to a calm state.

A training program for state observation was developed. Coders were first introduced to the six states and spent time in the nursery freely observing infants. After this introduction, coders scored a training tape of infants in their cots, including infants of different ages and medical risks, in real time using a hidden beeper that beeped every 10 s. When 85% reliability was reached on the tape, coders were trained in the nursery. The reliability of each coder (8 students of psychology) was measured against that of the program manager, who was trained by the chief neonatologist. Reliability for the coding of 12 infants at each age averaged 88% (kappa = .77).

Emotion Regulation, Reactivity, and Arousal Modulation at 3 Months

Emotion regulation, reactivity, and arousal modulation were measured with the Behavior Response Paradigm (BRP; Garcia-Coll et al., 1988). In this procedure, infants are presented with 17 stimuli in various modalities (e.g., sound, light). Each stimulus is presented for 20 s, with a 10-s break between stimuli. Stimuli are organized in a sequence of increasing complexity and intrusiveness, ranging from simple unimodal stimuli to aversive, multimodal stimuli (e.g., a fast-moving car flashing lights and making loud noises). Infants sat in an infant seat, and a trained examiner presented the stimuli in a predetermined order.

To assess regulation, we used a stage approach to soothing the infant when he or she cried. Each stage was attempted for 10 s, and when a stage was unsuccessful, the examiner moved to the next stage. The first stage consisted of waiting for the infant to self-soothe; this stage was followed by talking to the infant in a calm voice, offering a pacifier, picking the infant up, handing the infant to the mother, and terminating the procedure until the infant calmed.

Mother–Infant Shared Attention and Infant Sustained Exploration at 6 Months

Mother–infant shared attention and infant sustained exploration were observed during a mother–infant toy exploration session in the laboratory. The mother was given a basket with six age-appropriate toys and was asked to play with the infant while using these toys. The infant was placed in an infant seat mounted on a table, and the mother sat across from the infant. The mother and the infant were videotaped in a split-screen format from a control room, and the final picture showed a split frame of the mother's face and the infant's face and upper body. Ten minutes of dyadic play were videotaped.

Measures

Infant Medical Risk

Infant medical risk was measured with the Clinical Risk Index for Babies (CRIB; International Neonatal Network, 1993). The CRIB is an objective quantitative measure of neonatal risk for infants born prematurely. Each of the following items receives a certain score according to a predetermined range: birth weight, gestational age, minimum and maximum fraction of inspired oxygen, minimum base excess during the first 12 hr, and presence of congenital malformations. Scores are then summed to create the total CRIB score. The CRIB has been validated to be a more robust index of severity of disease than is birth weight alone. The CRIB was completed for each infant by the chief neonatologist in Hospital A and by the head nurse in Hospital B. Infants were assigned to high- and low-risk groups with the use of a median split of the CRIB score.

State Distribution and Sleep–Wake Cyclicity

Two sets of variables were quantified from the 4-hr observations at the hospital.

State distribution. The percentage of time infants spent in each of the six states was assessed.

Sleep–wake cyclicity. The rhythmic organization of each time-series of states, consisting of 1,440 data points (10-s epochs over 4 hr), was analyzed according to the procedure detailed by Gottman (1981). Prior to spectral analysis, linear trends were removed to improve stationary conditions (i.e., the consistency of the mean and the variance across time). The residualized time-series was analyzed with Blackman–Tukey Fourier analysis. Fourier analyses decompose the time-series into separate cycles superimposed on a constant, and each cycle is defined by its power (amplitude) and frequency. Spectral analysis was computed using a Tukey–Hanning smoothing function. The variable used to index sleep–wake cyclicity was the amplitude (power) of the basic cycle, the tallest spike in the periodogram (the visual display of the spectral analysis function). High amplitude (or power) of the basic cycle implies that more variance in infant states can be accounted for by rhythmic oscillations between sleep and wakefulness. The amplitude of the basic cycle has been used as a predictor variable in previous research. It was found to differentiate the organization of heart rhythms in healthy and at-risk neonates (Zeskind, Goff, & Marshall, 1991). In assessing infants' arousal during habituation, amplitudes were related to the efficiency of information processing at 3 months (Feldman & Mayes, 1999).

Emotion Regulation, Reactivity, and Arousal Modulation at 3 Months

Emotion regulation, reactivity, and arousal modulation were coded from the BRP. Microanalytic coding was conducted with the use of a computerized system (The Observer, Noldus Co., Wageningen, the Netherlands), and approximately 3–4 observations were required to code each session. Coding considered five channels of infant behavior, and codes within each channel were mutually exclusive. Channels and codes were as follows: *gaze*—to examiner, to stimulus, gaze aversion; *affect*—positive, neutral, and negative; *movement*—gross motor only, fine motor only, gross and fine motor simultaneously; *regulation*—self-soothing, talked to, pacifier, being picked up, being handed to the mother, and not being soothed; *reactivity*—high, mid-range, and none. Periods of "stimulus on" and "stimulus off" and whether the stimulus was social or nonsocial were also coded.

Regulation was coded after the coder observed the entire cry episode and determined at which stage the infant stopped crying. Reactivity was coded in a separate viewing on the basis of facial expressions, eye movements, hand and body movements, orientation, muscle tone, and level of arousal. No reactivity implied that the infant showed no signs of reaction to the stimulus or to any internal or external input. Medium-range reactivity indicated that the infant showed interest and a moderate level of excitement as indexed by gaze and body orientation, neutral or positive facial expressions, and fine and gross motor movements. High reactivity implied a high level of negative (e.g., crying combined with body arching and leg movements) or positive (e.g., clear laugh, enjoyable vocalizations, exuberance) arousal.

Two coders coded the BRP while the tape was running in real time in a continuous mode; they shifted to a slow-motion mode to determine the beginning and end of states or short events. Reliability was examined for 15 infants and exceeded 87% on all channels. Mean reliability was 92% (kappa = .81).

The relative proportions of all variables coded from the BRP were assessed. The following variables were used to index emotion regulation, reactivity, and arousal modulation.

Emotion regulation. Emotion regulation was indexed by two variables: threshold and soothability. Latency to the first cry was used to index the threshold to negative emotionality. Because the stimuli became progressively more intrusive, longer latencies to the first cry implied that the infant began to cry during the more aversive stimuli. The threshold variable was log transformed prior to data analysis. Duration of "stimulus off" was used as a measure of soothability. If the infant did not cry, the stimulus-off duration was fixed (10 s between each stimulus). When the infant cried, stimulus presentation stopped, and the six stages of regulation were tried one by one. Thus, the longer the stimulus-off period, the more difficult it was to regulate the infant and resume stimulus presentation.

Reactivity. Reactivity was indexed by the relative proportions of high, mid-range, and no reactivity during the BRP.

Arousal modulation. The proportions of high, mid-range, and no reactivity during "stimulus on" or "stimulus off" (conditional probabilities: e.g., duration of mid-range reactivity divided by duration of "stimulus on") were used as measures of arousal modulation. These variables considered the extent to which reactivity was sensitive to stimulus onset and offset, that is, whether the infant reacted during "stimulus on" and refrained from reactivity during "stimulus off." Two variables were of special interest as measures of optimal reactivity to stimulation: *mid-range reactivity during "stimulus on"*—the relative proportion of time the infant spent in mid-range reactivity during the stimulus-on period; *no reactivity during "stimulus off"*—the relative proportion of time the infant spent in no reactivity during the stimulus-off period.

Mother–Infant Shared Attention and Infant Sustained Exploration at 6 Months

Microanalysis of the toy exploration session was conducted like the analysis of the BRP. Sessions were coded in real time, and approximately 3–4 observations were required to complete the coding. Codes within each channel were mutually exclusive. The following channels of behavior were coded for the infant: *infant gaze*—to object (other than the object of shared attention), to partner, gaze aversion, shared attention (coded for mother also); *infant affect*—positive, neutral, negative, and tired; and *infant toy manipulation*—no interest in the toy, mouthing, manipulation of the toy with two hands, and sustained exploration. The following channels were coded for the mother: *mother gaze* and *mother affect* (coded like *infant gaze* and *infant affect*); *mother toy presentation*—no presentations of the toy, hands the toy to the infant, demonstrates the use of the toy, physically manipulates the infant's hands, takes the toy away, and joint manipulation of the toy with the infant. Reliability was examined for 20 infants and mothers. Reliability for all behaviors exceeded 88%, and the mean reliability was 93% (kappa = .83).

The relative proportions of all variables were computed, and two variables were of special interest. *Mother–infant shared attention* was defined, in line with Landry (1986), as a period in which the infant was looking at the same toy as the mother, a stage preceding the development of full joint attention skills (Bakeman & Adamson, 1984). Both the proportion of shared attention and the latency (in seconds) to the first episode of shared attention were assessed. *Infant sustained exploration* was defined as a period in which the infant explored the object both visually and manually, manipulated it with two hands and with visible interest, and engaged in active exploration for at least 2 s. Sustained exploration was coded after the entire exploratory episode was observed and its length and quality were determined. Both the proportion of and the latency to sustained exploration were assessed.

Results

The results are reported in three sections. In the first, multivariate analyses of variance (MANOVAs) are used to examine the effects of KC on state organization at 32 weeks and at term age. In the second, the effects of KC on infants' emotion regulation, reactivity, and arousal modulation at 3 months are reported. In the third section, the effects of KC on mother–infant shared attention and infants' sustained exploration are reported. In the following analyses, medical risk and multiple birth status were also examined as between-subjects factors. Developmental outcomes in premature infants are related to the degree of medical risk at birth (Dammann et al., 1996; McCormick, Workman-Daniels, & Brooks-Gunn, 1996), and slower cognitive development has been reported for twins than for singletons (Lytton, Watts, & Dunn, 1987). These factors were thus examined in relation to the measures of emotion and attention regulation examined here.

Effects of KC on Infants' State Organization in the Neonatal Period

State Distribution

A MANOVA with group (KC vs. control), medical risk (high vs. low), and multiple birth status (singletons vs. twins) as the between-subjects factors was conducted for the six behavior states at 32 weeks. No overall main or interaction effects were found, which suggests that the two groups were comparable prior to the initiation of KC.

A similar MANOVA for the six states at term revealed a significant effect for group, Wilks's $F(6, 133) = 4.21$, $p < .01$. Univariate analyses of variance (ANOVAs), reported in Table 2, show that KC infants spent longer portions of the 4-hr observation period in quiet sleep and alert wakefulness and less time in active sleep than did controls. A similar MANOVA for the six states at term revealed a significant effect for group, Wilks's $F(6, 133) = 4.21$, $p < .01$. Univariate analyses, reported in Table 2, show that KC infants spent longer portions of the 4-hr observation period in quiet sleep and alert wakefulness and less time in active sleep than did controls. A significant overall interaction effect was found for group and multiple birth, Wilks's $F(6, 133) = 2.56$, $p < .05$. Univariate analyses suggested that the source was quiet sleep. Mean percentages of quiet sleep were 40.77 ($SD = 18.54$) for singletons and 39.11 ($SD = 17.18$) for twins in the KC group and 34.70 ($SD = 19.22$) for singletons and 19.61 ($SD = 12.17$) for twins in the control group. These results indicate that the effect of KC on infants' state organization was larger for twins than for singletons.

Sleep–Wake Cyclicity

A univariate ANOVA with group, medical risk, and multiple status as between-subjects factors was conducted for sleep–wake cyclicity at 32 weeks and revealed no main or interaction effects. A univariate analysis for sleep–wake cyclicity at term revealed a significant effect for group, $F(1, 138) = 6.44$, $p < .01$, indicating better organization of sleep–wake states following KC.

To examine the development of sleep–wake cyclicity from 32 weeks gestation to term, we conducted a repeated measures univariate ANOVA with group, medical risk, and multiple birth status as between-subjects factors. A significant effect was found for time, $F(1, 137) = 4.11$, $p < .05$, suggesting that sleep–wake cyclicity increased during this period for all infants. A significant interaction was found for time and group, $F(1, 137) = 19.11$, $p < .01$. Although sleep–wake cyclicity increased for all infants, gains in the rhythmicity of sleep and wakefulness for infants receiving KC were higher. A significant overall effect was found for medical risk, $F(1, 137) = 4.41$, $p < .05$. Infants born at higher medical risk showed lower sleep–wake cyclicity at both ages. Mean amplitudes for sleep–wake cyclicity at 32 weeks were 10.97 ($SD = 11.46$) for the low-risk infants and 8.92 ($SD = 11.66$) for the high-risk infants. Mean amplitudes at term were 16.89 ($SD = 12.47$) for the

Table 2
Univariate Analysis of State Organization in Kangaroo Care and Control Infants

	Kangaroo care		Control		
Variable	*M*	*SD*	*M*	*SD*	Univariate *F*
		32 weeks			
Quiet sleep	31.16	23.84	30.97	19.15	*ns*
Active sleep	41.96	21.16	43.26	27.04	*ns*
Sleep–wake transition	7.93	9.23	7.49	8.37	*ns*
Unfocused wakefulness	6.46	7.63	6.61	7.85	*ns*
Alert wakefulness	3.03	5.12	2.96	3.53	*ns*
Fuss/cry	2.62	4.73	3.39	5.70	*ns*
Sleep–wake cyclicity	9.16	10.67	9.88	9.43	*ns*
		Term			
Quiet sleep	40.11	17.89	31.00	19.17	9.86**
Active sleep	30.23	15.48	40.43	20.99	7.78**
Sleep–wake transition	9.29	8.03	10.47	12.70	*ns*
Unfocused wakefulness	7.07	6.96	7.47	6.97	*ns*
Alert wakefulness	7.21	12.21	3.59	7.02	3.98*
Fuss/cry	3.90	6.81	3.50	4.61	*ns*
Sleep–wake cyclicity	17.30	12.28	11.57	10.38	6.38**

Note. Numbers for states represent the percentage of time infants spent in each state; numbers for sleep–wake cyclicity represent amplitudes resulting from the Fourier analysis. Univariate *F* measured group differences between kangaroo care infants and controls.
* $p < .05$. ** $p < .01$.

low-risk infants and 12.62 ($SD = 10.30$) for the high-risk infants. Thus, even when high-risk premature infants reach term, their state regulation is less mature than that of infants born at lower risk.

Individual stability in sleep–wake cyclicity from 32 weeks gestation to term was examined, and modest stability was found ($r = .30$, $p < .01$). A repeated measures ANOVA showed that active sleep decreased from 32 weeks gestation to term, $F(1, 137) = 3.78$, $p < .05$, whereas alert wakefulness increased, $F(1, 137) = 6.38$, $p < .01$.

Effects of KC on Infants' Regulation, Reactivity, and Arousal Modulation at 3 Months

A MANOVA with group, medical risk, and multiple status as the between-subjects factors was conducted for gaze, affect, movement, regulation, reactivity, and arousal modulation during the BRP. An overall group effect was found for gaze, Wilks's $F(3, 124) = 2.97$, $p < .05$. As can be seen in the univariate analyses presented in Table 3, KC infants looked more at the stimulus, whereas control infants had higher proportions of gaze aversion. An overall group effect was also found for affect, Wilks's $F(3, 124) = 2.99$, $p < .05$. As can be seen in Table 3, KC infants spent more time in positive and neutral affect than did controls. No overall effects were found for movement (gross or fine).

Emotion Regulation

No overall effects of KC were found for the different stages of regulation, $\chi^2(6, N = 87) = 1.05$, *ns*. A MANOVA with group, medical risk, and multiple birth status as the between-subjects factors for the two derived measures of regulation (threshold and soothability) revealed a significant group effect, Wilks's $F(2, 125) = 3.34$, $p < .05$. As can be seen in Table 3, univariate analyses showed group differences in thresholds to negative emotionality. Although there was no significant difference in the number of infants who cried during the procedure in the two groups, $\chi^2(1, N = 87) = 1.13$, *ns*, thresholds were higher among KC infants, and they tended to cry only during the more aversive stimuli. Thus, it appears that it took more aversive stimulation to make KC infants cry than to make controls cry. Contrary to our hypothesis, sleep–wake cyclicity at term was unrelated to soothability ($r = -.11$, *ns*). Sleep–wake cyclicity was related to a longer threshold to negative emotionality ($r = .19$, $p < .05$).

Reactivity

A MANOVA with group, medical risk, and multiple birth status as between-subjects factors was performed for the reactivity variables (proportions of high, mid-range, and no reactivity) and showed no main effect for group, Wilks's $F(3, 124) = 1.40$, $p > .10$. The findings indicate that KC did not have a significant effect on the infants' overall reactivity to external stimulation.

Arousal Modulation

As opposed to the measures of reactivity, a MANOVA with group, medical risk, and multiple birth status as between-subjects factors performed on the arousal modulation variables (proportions of high, mid-range, and no reactivity during "stimulus on") showed a significant overall effect for group, Wilks's $F(3, 124) = 8.29$, $p < .01$. Univariate tests are reported in Table 3. These data point to significant differences between KC infants and controls on mid-range and no reactivity during "stimulus on" because KC infants showed higher proportions of mid-range reactivity and lower proportions of no reactivity during the "stimulus on" period. A significant overall effect was also found for medical

Table 3
Univariate Analysis of Infant Reactivity and Regulation at 3 months

	Kangaroo care		Control		
Variable	*M*	*SD*	*M*	*SD*	Univariate *F*
Gaze					
Gaze to stimulus	.42	.13	.36	.13	5.53*
Gaze to examiner	.21	.15	.20	.12	*ns*
Gaze aversion	.36	.17	.42	.17	4.20*
Affect					
Positive affect	.07	.10	.04	.06	5.01*
Neutral affect	.86	.13	.76	.17	7.02**
Negative affect	.05	.06	.07	.08	*ns*
Emotion regulation					
Soothability (stimulus off)	.27	.08	.32	.10	*ns*
Threshold (latency in seconds to first cry)	83.00	122.38	63.66	104.64	5.54**
Reactivity					
High reactivity	.02	.04	.06	.08	*ns*
Mid-range reactivity	.64	.14	.63	.15	*ns*
No reactivity	.33	.14	.30	.15	*ns*
Arousal modulation					
High reactivity/stimulus on	.04	.04	.06	.07	*ns*
Mid-range reactivity/stimulus on	.59	.13	.52	.15	4.13*
No reactivity/stimulus on	.06	.08	.14	.11	18.11**

Note. Except for Threshold, numbers represent the proportion of time the infant spent in each state.
* $p < .05$. ** $p < .01$.

risk, Wilks's $F(3, 124) = 2.78$, $p < .05$. Univariate tests revealed that high-risk infants showed more high reactivity during "stimulus on" ($M = .06$, $SD = .05$) than did low-risk infants ($M = .04$, $SD = .04$). No main or interaction effects were found for multiple birth status for any of the variables at 3 months.

As hypothesized, sleep–wake cyclicity at term was related to arousal modulation. The correlation between sleep–wake cyclicity at term with mid-range reactivity during "stimulus on" was .20 ($p < .05$); and that between sleep–wake cyclicity and no reactivity during "stimulus off" was .28 ($p < .01$).

To further examine the topic of arousal modulation—that is, the extent to which infant reactivity synchronizes with the presentation and termination of the stimulus—we computed the ratio of each type of reactivity during "stimulus on" to its total proportion (e.g., high reactivity during "stimulus on" divided by high reactivity total). These variables assessed what proportion of each type of reactivity occurred during the stimulus-on period. The ratio of high reactivity during "stimulus on" to the high reactivity total was .89 ($SD = .16$) for the KC group and .75 ($SD = .21$) for the control group, $F(1, 133) = 6.14$, $p < .01$. The corresponding ratio for mid-range reactivity was .92 ($SD = .10$) for KC infants and .82 ($SD = .10$) for the controls, $F(1, 133) = 17.48$, $p < .01$, and the ratio for no reactivity was .22 ($SD = .30$) for KC infants and .48 ($SD = .24$) for the controls, $F(1, 133) = 21.19$, $p < .01$. These findings indicate that high and mid-range reactivity were more specific to the periods of stimulus presentation for infants who received skin-to-skin contact than for controls. Conversely, KC infants were more adept at using the stimulus-off period for rest and no reactivity. These data point to the contribution of skin-to-skin contact to the premature infant's ability to modulate arousal in accordance with the presentation and termination of external stimulation.

Effects of KC on Mother–Infant Shared Attention and Sustained Exploration at 6 Months

A MANOVA was computed for four clusters of variables from the toy exploration session: infant gaze, infant affect, infant toy manipulation, and mother toy presentation. Group, medical risk, and multiple birth status were entered as the between-subjects factors. An overall effect for group was found for infant gaze, Wilks's $F(4, 122) = 4.19$, $p < .01$. Univariate effects, reported in Table 4, show significant group differences in infant gaze to object and in shared mother–infant attention. KC infants and their mothers engaged more in shared attention, whereas controls looked more at objects that were out of the mother's visual focus. No overall group effects were found for infant affect.

An overall group effect was found for mother toy presentation, Wilks's $F(6, 120) = 5.51$, $p < .01$. Univariate analyses, reported in Table 4, show significant group effects for the mother handing the toy to the infant, taking the toy away, and joint manipulation of the toy with the infant. Although the overall time mothers in the two groups spent playing with the infants while using the toys was similar, as indicated by the lack of group differences in "no manipulation," mothers in the two groups used different techniques to engage their infants with the toys. Mothers of KC infants spent more time in joint manipulation, whereas mothers of controls tended to introduce new toys to the child. An overall effect for group was also found for infant toy manipulation, Wilks's $F(4, 122) = 4.48$, $p < .01$. As can be seen in Table 4, control infants spent more time manipulating the toy with two hands, whereas KC infants had longer periods of sustained exploration. No overall main or interaction effects were found for medical risk and multiple birth status at 6 months. Group differences for the two latency variables—latency to mother–infant shared attention and to infant

Table 4
Univariate Analysis of Toy Exploration at 6 months

Variable	Kangaroo care *M*	Kangaroo care *SD*	Control *M*	Control *SD*	Univariate *F*
Infant gaze					
To partner	.12	.19	.16	.21	*ns*
To object	.22	.28	.38	.23	12.28**
Gaze aversion	.05	.06	.08	.15	*ns*
Shared attention	.60	.29	.36	.33	17.48**
Mother toy presentation					
No manipulation	.34	.18	.33	.22	*ns*
Hands toy	.10	.09	.18	.12	15.07**
Demonstrates toy	.35	.20	.36	.21	*ns*
Physical manipulation	.04	.07	.04	.06	*ns*
Takes toy away	.02	.03	.04	.08	3.59*
Joint manipulation	.11	.09	.05	.08	9.22**
Infant toy manipulation					
No manipulation	.35	.21	.36	.23	*ns*
Mouthing	.25	.21	.22	.21	*ns*
Two-hand manipulation	.26	.18	.35	.24	4.33*
Sustained exploration	.10	.09	.04	.08	10.20**
Latency (seconds)					
To shared attention	59.42	55.98	74.33	48.36	3.76*
To sustained exploration	75.45	65.25	112.61	91.28	3.82*

Note. Except for Latency, numbers represent proportion of time the infant or the mother spent in each state.
* $p < .05$. ** $p < .01$.

sustained exploration—were computed after these variables were log transformed. Results of the ANOVAs, presented in Table 4, show that dyads in the KC group settled faster into shared attention and that KC infants were quicker to reach episodes of sustained exploration. As hypothesized, mother–infant shared attention and infant sustained exploration at 6 months were related to sleep–wake cyclicity. The correlation between sleep–wake cyclicity and shared attention was .21 ($p < .05$), and that between sleep–wake cyclicity and sustained exploration was .25 ($p < .01$).

The relations between (a) emotion regulation (soothability, threshold) and arousal modulation at 3 months and (b) sustained exploration and shared attention at 6 months were examined with Pearson correlations. Mother–infant shared attention was not related to soothability ($r = .04$) or to the threshold latency to negative emotionality ($r = .07$), but relations were found between shared attention and arousal modulation: with mid-range reactivity during "stimulus on" ($r = .34$, $p < .01$) and with no reactivity during "stimulus off" ($r = .20$, $p < .05$). Sustained exploration was related to threshold ($r = .28$, $p < .01$) but not to soothability ($r = .08$, *ns*). Sustained exploration was related to arousal modulation: to mid-range reactivity during "stimulus on" ($r = .31$, $p < .01$) and to no reactivity during "stimulus off" ($r = .39$, $p < .01$). Shared attention and infant sustained exploration were significantly correlated ($r = .30$, $p < .01$).

Comparisons Between KC Infants in the Two Sites and the Controls

Finally, to address the potential confounding effect of hospital site on the findings, in the Appendix we present means for all variables for which significant differences between KC infants and controls were found. Means are presented for three groups: KC—Hospital B ($n = 53$), KC—Hospital A ($n = 20$), and Controls—Hospital A ($n = 73$). Univariate ANOVAs with post hoc Duncan's tests were computed to examine differences between the three groups. As can be seen in the Appendix, the means for the KC groups in the two hospitals are comparable and depart significantly from those of the controls. No significant differences between the two KC groups were found for any of the variables. Furthermore, on most variables, post hoc comparisons confirmed significant and separate effects between each of the KC groups and the controls. These results demonstrate that the effect of KC on the outcome measures reported here is not an artifact of the difference in hospital sites.

In sum, the results of this study—among the first to examine the effects of skin-to-skin contact on infants' self-regulation—indicate that KC contributed to the development of self-regulation in premature infants. Infants receiving KC in the neonatal period showed more organized sleep–wake cyclicity at term, demonstrated better regulation of negative emotions and efficient arousal modulation when presented with complex stimuli at 3 months, and were more competent in exploring new objects with their mothers at 6 months.

Discussion

Although the clinical situation of early and persistent maternal separation modified by periodic body contact is relatively rare, the study of such a condition has major practical and theoretical value. The prematurity condition and the "kangaroo care" intervention method afford the opportunity to examine the issue of maternal proximity and the maturation of regulatory functions in a human model. The results of this study suggest that early skin-to-skin contact contributes to behavior organization and emotion regulation. Infants who received such contact prior to term showed more organized sleep–wake cyclicity and were more adept at regulating negative emotions, modulating arousal, sharing engagement with the mother and an object, and sustaining effortful exploration.

The results lend support to each of the theoretical perspectives outlined earlier. The perspective that considers the effects of maternal separation and contact during early infancy is supported by the data showing that full maternal contact during the first postbirth period has a lasting effect on the biological clock and on emotion regulation and attention. In line with Gottlieb's (1976) perspective, the data suggest that providing tactile and proprioceptive stimulation during periods when the sequential development of the senses is disturbed contributes to the organization of behavior. The perspective on the contribution of maternal proximity to the patterning of behavior (Hofer, 1973, 1984, 1995) is also supported by the results. Following KC, infants were better able to organize activity and rest in patterned sequences. This ability was expressed in organized sleep–wake cyclicity and more appropriate modulation of arousal in accordance with stimulus presentation and termination. These indices of behavior inhibition—state cyclicity and arousal modulation—were related to the infant's exploratory skills at 6 months, findings in line with theories that point to the role of behavior inhibition in the development of cognitive competencies (Dempster, 1991).

Maternal proximity is a construct that describes the mother's physical presence in its entirety and includes a range of interconnected stimuli: maternal smell, touch, voice, body heat, skin texture, movement, physiological rhythms, nursing, and the mother's unique social and affective style. The physiological and neuroendocrine elements provided by the mother's presence and interactions provide the basis for the development of infants' stress tolerance, emotion regulation, and attention organization (Schore, 1996). Providing premature infants with separate components of the maternal proximity constellation (rhythmic stimulation, sensory enrichment, tactile stimulation) was found to have a positive impact on later development (Feldman & Eidelman, 1998). Horowitz (1990) theorized that all intervention programs affect the development of premature infants through their positive impact on the arousal system and the capacity of the arousal system to regulate states of hyper- or hypo-arousal, but few empirical data support this hypothesis. The present findings support this hypothesis by showing that the mother's full physical proximity contributes to the regulation of physiological, emotional, and cognitive skills.

The first impact of skin-to-skin contact on arousal regulation was manifest in the finding that KC infants showed better state organization upon reaching term. Two measures were used to measure state organization: the distribution of states and sleep–wake cyclicity. It has been suggested that state regulation develops in two stages. In the first, a more optimal distribution of states emerges, and quiet sleep and wakeful alert periods increase while active sleep and transitory states decrease. This stage is followed by the consolidation of sleep–wake cyclicity (Fiaenza, Capone, & Galgano, 1986; Ingersoll & Thoman, 1999). Infants who received

KC spent longer periods in quiet sleep and wakefulness and shorter periods in active sleep, results in line with previous KC research (Ludington & Golant, 1993). The findings are also in line with studies that link biobehavioral maturity in the neonatal period with increased periods of quiet sleep and decreased active sleep (e.g., Holditch-Davis, 1990).

It is interesting that KC had a more notable effect on state organization in twins than in singletons. This finding may be interpreted in line with Hofer's (1995) work on the relations between maternal proximity and the infant's physiological homeostasis. Possibly, very-low-birth-weight premature twins have decreased opportunities for maternal proximity compared with singletons even when their medical conditions allow for full maternal contact. Mothers of premature twins may have been overwhelmed by the physical and emotional needs of two sick infants and may have gone through more straining pregnancies. Our intervention required mothers of twins to spend at least 1 hr per day in full bodily contact with each of their twins, and the contribution of maternal contact to each child's state organization may have been greater for such twins than for high-risk twins whose mothers did not make such a commitment. Minde, Corter, Goldberg, and Jeffers (1990) found that mothers of high-risk twins developed a preference for one infant immediately after birth, that this preference remained stable across infancy, and that maternal preference predicted the child's cognitive and social-emotional development at 4 years. These findings, combined with the present results, emphasize the need to assist the mother in bonding with each of her twins immediately after birth, using interventions such as KC.

In addition to improvement in state organization, KC had a positive impact on the infants' sleep–wake cyclicity. To date, outcomes of variations in sleep–wake cyclicity have received surprisingly little empirical attention, even though theoretical accounts consider the biological clock as the foundation of attention, information processing, and emotion regulation (Dahl, 1996; Sander, 1987; Winfree, 1980; Wolff, 1967; Wright & Harding, 1992). Thus, the present findings showing that infants with more organized sleep–wake cyclicity at term age also show better arousal regulation and exploration in the first months of life provide empirical evidence for these theories. The measure of sleep–wake cyclicity used here may serve as an early indicator for the development of arousal regulation and attention. The findings that sleep–wake cyclicity showed a degree of stability from 32 weeks gestation to term and that it differentiated between infants born at high and low risk also suggest that this measure captures an aspect of the infant's neurobehavioral maturation and may serve as a clinical tool.

The results may also help specify mechanisms through which maternal contact may contribute to the development of self-regulation. Hofer (1984, 1995) suggested that maternal contact establishes a protective function by raising the infant's tolerance to aversive stimuli in the environment, and this protective function in turn promotes attention and exploration. Consistent with this perspective, the present data show that maternal proximity helped increase the infant's threshold to negative emotions. This was expressed in the finding that although there was no difference between the number of infants who cried during the BRP in the two groups, infants who received KC cried only during the more aversive stimuli, implying that it took more aversive stimulation to make these infants cry. Furthermore, following skin-to-skin contact, infants' visual attention was better suited for efficient processing of the task at hand, which points to the relations between maternal proximity and attention processes. At term, KC infants spent longer periods in attentive alertness. At 3 months, KC infants looked more at the stimulus and had shorter periods of gaze aversion when presented with novel stimuli. At 6 months, when infants begin to actively use the mother to acquire information about objects (Bakeman & Adamson, 1984), KC infants were better able to establish moments of shared attention. Although the achievement of shared attention is related to maternal as well as infant skills, the gains in infant attention regulation following KC may have increased the dyadic capacity to engage in shared attention.

Premature infants often present an abnormal reactivity to environmental stimuli. Such disruptions are expressed either in the form of hypo-reactivity, conceptualized as a protective mechanism against stimulus overload, or as hyper-reactivity, resulting from immature self-regulatory mechanisms (Tronick, Scanlon, & Scanlon, 1990). Comparisons of KC and control infants on total reactivity scores showed few mean-level differences, possibly because of the U-shaped curve of optimal reactivity. Assessment of reactivity over time, however, revealed significant group differences, particularly on the ability to synchronize reactivity with stimulus presentation and termination. Infants who received KC typically showed mid-range reactivity while the stimulus was on and no reactivity while the stimulus was off. Compared with full-term infants, premature infants often have difficulty in inhibiting reactivity, which interferes with the development of efficient information processing and the maturation of cognitive competencies (Lester et al., 1990). The finding that infants born at higher risk showed higher reactivity during stimulus presentation similarly points to the relations between neurobehavioral immaturity and difficulties in the inhibition of reactivity. Following skin-to-skin contact, premature infants appear to be more skilled in inhibiting behavior, and this skill, in turn, may enable a more efficient processing of external information.

Mother–infant skin-to-skin contact contributed to the infant's attention and exploration at 6 months. Adamson and Russell (1999) suggested that joint attention skills in the second half-year—in particular, the ability to integrate the new focus on objects with attention to the social partner—emerge on the basis of emotion regulation skills acquired in the first months of life. The data show that infants' sustained exploration of toys with their mothers at 6 months was related to three earlier levels of regulatory processes: sleep–wake cyclicity, the regulation of negative emotions, and the modulation of arousal in accordance with external input. The theoretical link between the arousal system, the organization of behavior, and cognitive maturation has a long tradition (Hebb, 1949; Schnierla, 1957), and the present data are in line with these theories. Possibly, KC contributed to the infant's exploratory skills by providing an entire range of sensory experiences through the mother's full physical proximity, which facilitated cognitive development, while stimulation was being modified by the mother's presence and contact, which improved the development of self-regulation.

The development of mother–infant joint attention has been shown to be modified not only by the child's cognitive skills but also by the mother's attention-maintaining strategies, particularly among premature infants (Landry, 1995). Brachfeld, Goldberg, and Sloman (1980) showed that during play, mothers of premature infants tend to continuously introduce new toys to their infants, possibly as a reaction to the child's limited capacity for exploration and shared attention. As shown by the findings, mothers who provided KC during the neonatal period engaged more in shared attention and mutual exploration, whereas mothers of controls had more episodes of handing toys to and taking toys away from their infants. It is thus possible that in addition to the direct impact of skin-to-skin contact on the infant's attention regulation, KC may have facilitated a more sensitive and synchronous maternal style, thereby contributing to infant self-regulation indirectly through its impact on the mother and the mothering process.

Finally, the limitations of this study primarily relate to the fact that this was not a prospective randomized study of control infants and infants who received skin-to-skin contact. As noted, KC is not an experimental technique but is considered to be a standard care option, and thus randomization was precluded for ethical reasons. The fact that different hospitals have introduced KC methods at different periods provided an opportunity to compare control-matched mother–infant dyads from two hospitals who were being treated concurrently with otherwise similar clinical protocols, thus resolving the issue of bias in the historical controls. Similarly, selection bias that would have ensued from comparing infants of mothers who provided KC with infants of mothers who refused to provide KC was minimized. The data presented in the Appendix, which shows significant differences between each of the KC groups and the controls and no significant differences between the two KC groups, should minimize this concern. Still, it should be taken into consideration that some unknown or unmeasured variables may have differentiated the two sites.

The data point to the need to further study how early skin-to-skin contact affects infant neurobehavioral development and the parenting process. Future research should examine whether the gains reported for infants receiving early KC persist into later childhood and how these gains compare to those achieved by premature infants treated with standard incubator care. Finally, research should compare the effects of KC provided by caregivers other than the mother—such as fathers, grandmothers, siblings, the nursing staff, or trained volunteers—on various aspects of children's social and cognitive development. Such information can be useful in devising intervention programs for premature infants that best address their developmental needs and specific liabilities.

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Appendix

Group Differences Between Kangaroo Care Infants in the Two Hospital Sites and Controls

Variable	Group a: Kangaroo care, Hospital B ($n = 53$)		Group b: Kangaroo care, Hospital A ($n = 20$)		Group c: Control, Hospital A ($n = 73$)			
	M	*SD*	*M*	*SD*	*M*	*SD*	*F*	Comparison
Term age								
Quiet sleep (%)	40.93	17.09	40.01	16.45	31.00	19.17	12.98**	a > c, b > c
Active sleep (%)	32.30	19.79	29.65	14.04	40.43	20.99	6.07	a < c, b < c
Alert wakefulness (%)	7.43	12.82	6.77	9.83	3.50	7.02	3.77*	a > c
Sleep–wake cyclicity[a]	17.02	12.33	17.47	11.72	11.57	10.38	5.97	a > c, b > c
3 months								
Gaze to stimulus	.41	.15	.44	.13	.36	.12	3.65*	a > c, b > c
Gaze aversion	.34	.18	.38	.16	.42	.17	3.57*	a < c
Positive affect	.07	.11	.06	.10	.04	.06	3.76*	a > c
Neutral affect	.85	.13	.88	.15	.76	.17	4.91**	a > c, b > c
Threshold (seconds)	81.34	125.12	85.34	123.16	63.66	104.64	4.57**	a > c, b > c
Mid-range reactivity/stimulus on	.59	.13	.60	.11	.52	.15	3.73*	a > c, b > c
No reactivity/stimulus on	.06	.08	.07	.08	.14	.11	18.11**	a < c, b < c
6 months								
Infant gaze								
Gaze to object	.20	.29	.26	.23	.38	.23	8.25**	a < c, b < c
Shared attention	.58	.29	.63	.24	.36	.33	9.92**	a < c, b < c
Mother toy presentation								
Hands toy	.11	.09	.09	.08	.18	.12	7.96**	a < c, b < c
Takes toy away	.02	.03	.03	.04	.04	.08	3.37*	a < c
Joint manipulation	.10	.09	.11	.09	.04	.08	8.36**	a < c, b < c
Infant toy manipulation								
Two-hand manipulation	.24	.19	.30	.23	.35	.24	2.66	*ns*
Sustained exploration	.09	.09	.12	.10	.04	.08	12.39**	a < c, b < c

Note. Except when noted otherwise, numbers represent proportion of time spent in each state. Post hoc comparisons were computed with Duncan's test.
[a] Numbers represent amplitudes derived from Fourier analysis.
* $p < .05$. ** $p < .01$.

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