Maternal-Preterm Skin-to-Skin Contact Enhances Child Physiologic Organization and Cognitive Control Across the First 10 Years of Life

Ruth Feldman, Zehava Rosenthal, and Arthur I. Eidelman

Background: Maternal–newborn contact enhances organization of the infant's physiological systems, including stress reactivity, autonomic functioning, and sleep patterns, and supports maturation of the prefrontal cortex and its ensuing effects on cognitive and behavioral control. Premature birth disrupts brain development and is associated with maternal separation and disturbances of contact-sensitive systems. However, it is unknown whether the provision of maternal–preterm contact can improve long-term functioning of these systems.

Methods: We used the Kangaroo Care (KC) intervention and provided maternal–newborn skin-to-skin contact to 73 premature infants for 14 consecutive days compared with 73 case-matched control subjects receiving standard incubator care. Children were then followed seven times across the first decade of life and multiple physiologic, cognitive, parental mental health, and mother–child relational measures were assessed.

Results: KC increased autonomic functioning (respiratory sinus arrhythmia, RSA) and maternal attachment behavior in the postpartum period, reduced maternal anxiety, and enhanced child cognitive development and executive functions from 6 months to 10 years. By 10 years of age, children receiving KC showed attenuated stress response, improved RSA, organized sleep, and better cognitive control. RSA and maternal behavior were dynamically interrelated over time, leading to improved physiology, executive functions, and mother–child reciprocity at 10 years.

Conclusions: These findings are the first to demonstrate long-term effects of early touch-based intervention on children's physiologic organization and behavioral control and have salient implications for the care practices of premature infants. Results demonstrate the dynamic cascades of child physiological regulation and parental provisions in shaping developmental outcome and may inform the construction of more targeted early interventions.

Key Words: cortisol, executive functions (EF), Kangaroo Care, mother–infant relationship, longitudinal studies, premature infants, respiratory sinus arrhythmia (RSA)

The close contact between mother and young is a defining feature of mammals. The mother's physical presence and provision of species-typical postpartum behavior supports growth and thriving of mammalian young (1,2). Research in nonhuman mammals, mainly rodents, has shown that early maternal contact is accompanied by biobehavioral processes that promote physiologic and behavioral development and have an impact on the infant's brain systems that manage stress and enhance social adaptation (3,4). Early maternal deprivation, on the other hand, exerts lifelong negative effects on offspring (5). Being a mammal therefore implies that the brain is not fully formed at birth, and maturation of systems that enable adaptive functioning in the world are gradually acquired through close contact with an alert, responsive mother, albeit to varying degrees across species (6).

Not all systems are equally susceptible to maternal contact or deprivation (7). The hypothalamic-pituitary-adrenal (HPA) axis, which regulates cortisol production and the body's response to stress, organizes during an early period of neuroplasticity in response to maternal contact. Maternal licking and grooming alters glucocorticoid receptor gene expression in the rat pup's hippocampus, favorably enhancing stress regulation in the adult animal (8). Handled rats taken out of the home cage for several minutes daily display lower cortisol stress response as adults, possibly due to the increase in maternal behavior following return to the home cage (5,9). The autonomic nervous system, which regulates heart rhythms, matures through thermal, tactile, and nutritive stimuli provided by the mother's body (3), and the sleep–wake cycle is shaped by maternal physiologic and behavioral rhythms (10). These systems, which regulate the body's response to changing external demands, provide support to complex cognitive and social skills and moderate the ongoing transactions between the organism and its environment. Such environment-sensitive systems mature in the context of finely tuned synchronous adaptations between the infant's homeostatic states and social signals and the mother's moment-by-moment physiologic and behavioral response (11,12).

Premature birth is a major health care problem worldwide, associated with early and persistent maternal separation. Approximately 12% of infants in industrial societies and substantially more in developing countries are born annually at various degrees of prematurity, leading to increased mortality, morbidity, and measurable developmental delays (13). Although advances in medical technology enable the survival of smaller and sicker infants, many require months of intensive care that preclude full maternal–infant bodily contact (14). Premature birth disrupts brain development, leading to suppressed neurogenesis (15), decreased myelination (16), and white matter disturbances (17),

From the Gonda Multi-Disciplinary Brain Research Center (RF, ZR), Bar-Ilan University, Ramat-Gan, and Department of Pediatrics (AIE), Shaare Zedek Medical Center, and Hebrew University School of Medicine, Jerusalem, Israel.

Address correspondence to Ruth Feldman, Ph.D., Department of Psychology and the Gonda Multi-Disciplinary Brain Center, Bar-Ilan University, Ramat-Gan, Israel 52900; E-mail: feldman@mail.biu.ac.il.

Received Apr 6, 2013; revised Aug 5, 2013; accepted Aug 6, 2013.

0006-3223/$36.00
http://dx.doi.org/10.1016/j.biopsych.2013.08.012

and brain anomalies often persist into later childhood and adolescence (18,19). The combination of brain immaturity and maternal separation exerts long-term negative effects on development, particularly on systems sensitive to maternal separation. Prematurely born children exhibit disorganized sleep patterns (20,21), disturbances in HPA reactivity (22,23), and lower baseline respiratory sinus arrhythmia (RSA), indicating less functional autonomic nervous system (24,25). Abilities collectively referred to as executive functions (EF), which tap working memory, cognitive control, and mental flexibility and draw on the postnatal maturation of the prefrontal cortex (26), are also disturbed in premature children (27,28). Finally, premature birth disrupts the mother–infant bonding process, and mothers report greater stress, anxiety, and depression (29,30) and exhibit less optimal mother–infant interactions (31–33). Because development evolves from the cascading interactions of infant biological dispositions and parental provisions, difficulties in physiologic regulation and parenting behavior enhance each other over time, leading to maladaptive outcome (34,35). However, although ecological and multilevel developmental models describe such mutually influencing cascades as causal factors in the consolidation of early risk into childhood psychopathology (36), few studies tested physiological, cognitive, parental mental health, and mother–child relational factors across long epochs beginning at birth in relation to psychopathology and wellness.

Maternal–infant bodily contact may ameliorate some of the difficulties observed in contact-sensitive systems among premature infants. The Kangaroo Care (KC) intervention, initially developed in Bogota, Columbia, to cope with a lack of incubators, enables premature infants to maintain body heat through skin-to-skin contact with the parent's body (37). Research has demonstrated that KC is safe (37) and contributes to neuromaturation in premature infants during the neonatal period. Newborns receiving KC showed better autonomic maturity (38), electroencephalogram complexity (39), pain response (40), and physiologic stability (41). Similarly, KC improved mother–infant interaction (42,43), maternal–infant bonding (44), and maternal mood (42) in early infancy. Other touch-related interventions, such as massage, yielded similar short-term improvements, including weight gain, mother–infant interactions, and maternal mood (45–48). However, it is unknown whether any touch-based intervention carries lasting effects on children's development beyond infancy.

In the current study, we applied the KC intervention to premature infants and followed children seven times across the first decade of life, repeatedly testing physiologic, cognitive, mother–child relational, and parental mental health factors (Figure 1). Consistent with models on the dynamic cascades underpinning normative and pathologic development, we expected that the short-term gains reported for infant neuromaturation and mother–infant bonding following KC would enhance each other over time, leading to lasting gains. We hypothesized that 1) infants receiving KC would show more optimal physiologic functioning in contact-sensitive systems, including autonomic functioning, sleep organization, and HPA reactivity; 2) mother–child interactions would be more optimal following KC; 3) children

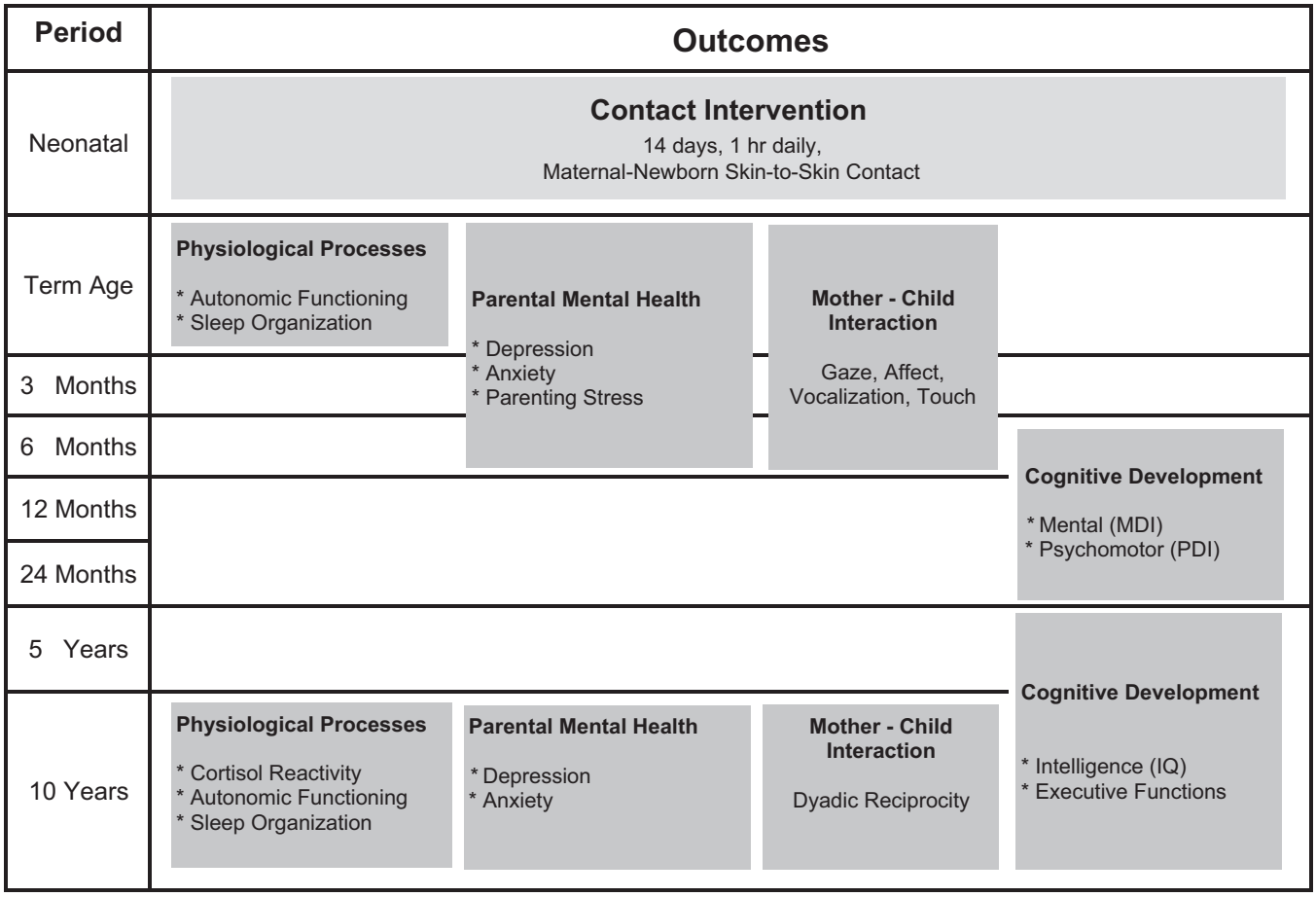

Figure 1. Overall study design testing the effects of maternal-preterm skin-to-skin contact across the first 10 years of life. MDI, Mental Development Index; PDI, Psychomotor Developmental Index.