BACK TO BASICS

A review of the scientific foundations of current clinical practice

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Attachment, Affect Regulation, and the Developing Right Brain: Linking Developmental Neuroscience to Pediatrics

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Editor's Note: *This article is a departure from our usual review in that it discusses new frontiers in the correlation of brain, mind, and emotions in developing children as well as areas of collaboration between pediatrics and sister disciplines. Dr Schore has adapted a substantial amount of technical information to the viewpoint of the pediatrician. At the same time, many readers will encounter perspectives and language that seem unfamiliar. We urge clinicians to invest the effort needed for a careful reading to appreciate exciting new ways to look at development and emotional coping mechanisms. Readers desiring an abbreviated version will find it in the print version. —LFN*

Introduction

We are in the midst of an exciting period for clinical practitioners, one in which the connections between the basic and applied sciences are being more tightly forged. A powerful engine driving this progression of knowledge is the recent remarkable advance in biotechnology, especially imaging technologies. Noninvasive studies of organ systems have increased substantially our understanding of the biologic processes that underlie various diseases of the body. At the same time, neuroimaging research of both psychological functions and psychiatric conditions has generated more complex models of normal and abnormal operations of the human mind. Another catalyst of the continuing dramatic increase in information is the rapid expansion of collaborative interdisciplinary research. Of particular relevance to pediatrics, this same time period has seen an explosion in infant research that integrates neurobiological studies of brain development and psychological studies of emotional, social, and cognitive development. Developmental studies, which span a spectrum of scientific and medical disciplines, now are serving as a convergence point for complex models of structure and function, brain, mind, and body.

A paradigm shift is occurring in the basic sciences that underlie pediatrics. Research in developmental biology and physiology now strongly supports a model of the "developmental origins of health and disease." (1) Although the role of early expressed genetic factors is an essential focus of current study, it has become clear that genes do not specify behavior absolutely; prenatal and postnatal environmental factors play critical roles in these developmental origins. The social environment, particularly the one created together by the mother and infant, directly affects gene-environment interactions and, thereby, has long-enduring effects.

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(2) The newer interdisciplinary models, therefore, detail the mechanisms by which "mother nature meets mother nurture." (3) Complimenting this conception of the nature-nurture problem, studies in neuroscience indicate that development represents an experiential shaping of genetic potential and that early experiences with the social environment are critical to the maturation of brain tissue. Thus, nature's potential can be realized only as it is facilitated by nurture. (4)

In parallel advances in developmental psychology and child psychiatry, attachment theory, initially proposed more than 35 years ago by John Bowlby (5) as a conception of the mother-infant relationship, has become the dominant model of human social-emotional development available to researchers and clinicians over a broad array of disciplines. In his attempt to integrate psychology and psychiatry with behavioral biology, Bowlby speculated that the attachment system, an evolutionary mechanism common to both humans and animals, ultimately would be located in specific areas of the brain. Updated models of attachment theory that emphasize both emotional and social functions and neurobiological structures now are interfacing with developmental neuroscience to generate a large body of interdisciplinary studies.

This recent information on the developmental origins of health and disease can be translated directly into clinical practice. It has both expanded the amount of factual knowledge and altered the theoretical constructs that model the diagnoses and treatments of a variety of psychological and physical disorders of childhood. These advances are, in turn, directly relevant to pediatricians' interest in the normal and abnormal functions of the developing child's mind and body. The common ground of the expanding body of knowledge in the developmental sciences, therefore, can strengthen the ties of pediatrics to the allied fields that border it: developmental neurology, child psychiatry, and developmental psychology.

This ongoing paradigm shift in the basic and applied sciences is expressed in three converging themes. The first arises from the wealth of neurobiological data that became available in the last decade, the "decade of the brain." These findings strongly support the idea that the most powerful conception of development may come from a deeper understanding of the brain's own self-organizing operations. Currently, there is an intense focus on the human brain growth spurt, which begins in the last trimester of pregnancy and continues to 18 to 24 months of age. Myelinization of the brain is so rapid and extensive at this time that the brain takes on an "adultlike" appearance by the end of the first postnatal year. (6) Neuroscientists are concluding that the accelerated growth of brain structure during critical periods of infancy is dependent on experience and influenced by "social forces." Neuropsychiatrists refer to "the social construction of the human brain" and posit that the cellular architecture of the cerebral cortex is sculpted by input from the social environment embedded in the early attachment relationships. These data suggest that "the self-organization of the developing brain occurs in the context of a relationship with another self, another brain." (7)

Furthermore, we now are aware that "the brain" actually is a system of two brains, each of which has very different structural and functional properties. Of particular interest to the developmental sciences is the early maturing right brain, which undergoes a growth spurt in the first 2 years, before the verbal left, and is dominant in the first 3 years after birth. (8) This growth is not encoded totally by the genome, but it is shaped indelibly by the emotional communications within attachment transactions. Because the right hemisphere is dominant for the emotional and corporeal self, (9) the social experience-dependent maturation of the right brain in human infancy is equated with the early development of the self. (10) The early development of the brain-mind-body, the origin of the self, therefore, is a reflection of the development of the right brain and its unique functions.

The second theme emerges from transformations within the psychiatric and psychological sciences. All subdisciplines within psychology, from developmental through abnormal, are shifting their focus from cognition to emotion. Research suggests that the attainment of an attachment bond of emotional communication and the maturation of affect represent the key events in infancy more so than does the development of complex cognitions. Models have moved from Piagetian theories of cognitive development to psychobiological models of social-emotional development. Clinical psychology and psychiatry are moving from cognition to emotion as the central force in psychopathology and psychotherapy. This emphasis on emotion also is reflected in: 1) the emergence of affective neuroscience and its focus on the specializations of the right hemisphere for processing affective states, and 2) psychiatry's current interest in the emotion-processing limbic system, the brain system that derives subjective information in terms of emotional feelings that guide behavior and functions to allow the individual to adapt to a

rapidly changing environment and organize new learning.

The third theme revolves around the critical concept of self-regulation. The process of development itself is believed to represent a progression of stages in which adaptive self-regulatory structures and functions enable new interactions between the individual and the social environment. It now is established that emotions are the highest order direct expressions of bioregulation in complex organisms, that the maturation of the neural mechanisms involved in self-regulation is experience-dependent, and that these critical affective experiences are embedded in the attachment relationship.

In other words, attachment relationships are essential because they facilitate the development of the brain's self-regulatory mechanism. Studies reveal that these essential self-regulatory structures are located in the right (and not left) brain. (11)(12) Consensus now indicates that attachment can be defined as the dyadic regulation of emotion, that the attainment of the self-regulation of affect is a major developmental achievement, and that normal development represents the enhancement of self-regulation.

I now use the perspective of regulation theory (10)(11)(12) to discuss and interpret recent studies on attachment, affect regulation, and development of the right brain. These advances in understanding the neurobiology of attachment are being incorporated into clinical models of the development of childhood mental health and mental illness, areas that are directly relevant to pediatrics. The mission statement of the American Academy of Pediatrics states its commitment to "the attainment of optimal physical, mental, and social health for all infants, children, adolescents, and young adults." (http://www.cispimmunize.org/mission.html)

For a more extensive discussion of regulation theory and an index of the references of studies cited here, the reader is referred to two books by Schore. (10)(11)

Interactive Affect Regulation: A Fundamental Mechanism of Attachment Dynamics

The primary goals for the infant during the first postnatal year are the creation of an attachment bond of emotional communication with the primary caregiver and the development of self-regulation. From birth onward, infants use their expanding coping capacities to interact with the social environment. In the earliest proto-attachment experiences, infants use their maturing motor and developing sensory capacities, especially smell, taste, and touch, to interact with the social environment. (13)(14) At around 8 weeks of age, there is a dramatic progression of social and emotional capacities. Within episodes of mutual gaze, the caretaker (usually the mother) and infant engage in nonconscious and spontaneous facial, vocal, and gestural communications. Such highly arousing, affect-laden, face-to-face interactions allow the infant to be exposed to high levels of social and cognitive information.

In face-to-face emotional transactions, the mother makes herself contingent, easily predictable, and manipulatable by the infant. To regulate the high positive arousal, the dyad synchronizes the intensity of their affective behavior within split seconds. These episodes of "affect synchrony" occur in the first expression of social play and generate increasing levels of joy and excitement. In these interactions, both partners match states and simultaneously adjust their social attention, stimulation, and accelerating arousal to each other's responses. According to Lester, Hoffman, and Brazelton, "synchrony develops as a consequence of each partner's learning the rhythmic structure of the other and modifying his or her behavior to fit that structure." (15) In such moments, the empathic caregiver's sensory stimulation coincides with the infant's endogenous rhythms, allowing the mother to appraise the nonverbal expressions of her infant's internal arousal and psychobiological states, regulate them, and communicate them back to the infant.

In this process of "contingent responsivity," the tempo of their engagement, disengagement, and reengagement is coordinated. The more the empathic mother tunes her activity level to the infant during periods of social engagement, the more she allows him or her to recover quietly in periods of disengagement. The more she attends to the child's reinitiating cues for re-engagement, the more synchronized becomes their interaction. Thus, the caregiver facilitates the infant's information processing by adjusting the mode, amount, variability, and timing of the onset and offset of stimulation to the infant's unique, temperamentally determined integrative capacities. These interactively regulated, synchronized interactions promote the infant's regulatory capacities and are fundamental to his or her healthy affective development.

In such interactions the mother must be attuned not so much to the child's overt behavior as to the reflections of the rhythms of his or her internal state, enabling the dyad to create "mutual regulatory systems of arousal." To regulate the infant's arousal, she must be able to regulate her own arousal state. The capacity of the infant to experience increasing levels of positive arousal states is am-

plified and externally regulated by the primary caregiver and depends on her capacity to engage in an interactive communication of emotions that generates feelings in herself and her child. Maternal sensitivity, therefore, acts as an external organizer of the infant's biobehavioral regulation.

Research also shows frequent moments of misattunement in the dyad or ruptures of the attachment bond. In early development, an adult provides much of the modulation of infant states, especially after a state disruption or a transition between states, and this intervention allows for the development of self-regulation. The key to this beneficial interaction is the caregiver's capacity to monitor and regulate her own (especially negative) affect. In this essential regulatory pattern of "rupture and repair," the attuned "good-enough" caregiver who induces a stress response in her infant through a misattunement remedies the situation and helps her infant regulate his or her negative affect via her participation in "interactive repair." The process of re-experiencing positive affect following negative experience allows the child to learn that negative affect can be tolerated and that relational stress can be regulated. Infant resilience emerges from an interactive context in which the child and parent together make the transition from positive to negative and back to positive affect. The adaptive regulatory capacity of resilience in the face of stress is an ultimate indicator of secure attachment and optimal mental health.

Affect synchrony that creates states of positive arousal and interactive repair that modulates states of negative arousal are the fundamental building blocks of attachment and its associated emotions. These arousal-regulating transactions, which continue throughout the first year, underlie the formation of an attachment bond of emotion regulation between the infant and primary caregiver. Indeed, psychobiological attunement and the interactive mutual entrainment of physiologic rhythms are fundamental processes that mediate attachment. Thus, throughout the life span, attachment is a primary mechanism for the regulation of biologic synchronicity within and between organisms.

These data clearly suggest that affect regulation is not just the reduction of affective intensity or the dampening of negative emotion. Affect regulation involves an intensification of positive emotion, a condition necessary for more complex self-organization. The attuned mother of the securely attached child not only minimizes the infant's negative states through comforting transactions but also maximizes his positive affective states in interactive play. Regulated affective interactions with a familiar, predictable primary caregiver create a sense of safety and a curiosity that fuels the child's exploration of novel socioemotional and physical environments. This ability is a marker of adaptive infant mental health.

Interpersonal Neurobiology of Right Brain–to–Right Brain Attachment Communications

Learning how to communicate emotional states is an essential developmental process. Because these communications are nonverbal and subjective, it was believed that their underlying mechanisms were unavailable to experimental analysis. However, studies in developmental psychobiology have offered important contributions to this problem, revealing that during optimal moments of bodily based affective communications, the adult's and infant's individual homeostatic systems are linked in a superordinate organization that allows for mutual regulation of vital endocrine, autonomic, and central nervous systems of both mother and infant by elements of their interaction with each other.

Basic developmental neurobiological research findings are consonant with the psychological models of early mother-infant communication described in the preceding section. Coordinated visual eye-to-eye messages, auditory vocalizations, and tactile and body gestures serve as channels of communicative signals that induce instant emotional effects: the positive feelings of excitement and pleasure build within the intersubjective field created by the dyad. According to Trevarthen, (16) the intrinsic regulators of a child's brain growth are adapted specifically for coupling, by emotional communication, to the regulators of adult brains.

Attachment communications, therefore, are "built into the nervous system," inducing substantial changes in the developing brain. Which parts of the brain are affected by the interactive regulation embedded within various types of visual, auditory, and tactile communications? Keeping in mind that the brain actually represents two unique hemispheric processing systems, a substantial body of research indicates that the right hemisphere begins a critical period of maturation before the left. This hemisphere is more advanced than the left in surface features from about the 25th gestational week until the beginning of the second postnatal year, when the left hemisphere undergoes a growth spurt. (17) Neuroimaging studies demonstrate that brain mass increases rapidly during the first 2 years after birth, normal adult appearance is seen at 2 years, and all major fiber tracts can be identified by age 3 years. Infants younger than 2 years of age

show higher right than left hemispheric volumes. (18)

Several studies support the principle that "the emotional experience of the infant develops through the sounds, images, and pictures that constitute much of an infant's early learning experience, and are disproportionately stored or processed in the right hemisphere during the formative stages of brain ontogeny." (19) The neurobiology of attachment, therefore, is an interpersonal neurobiology of right brain-to-right brain communications. Although the later developing left hemisphere mediates most language functions, the early developing right hemisphere is more important to the broader aspects of communication through all stages of life.

In support of this right brain-to-right brain communication model, research indicates that at about 8 weeks (onset of intense face-to-face communications), a critical period is initiated in the occipital cortex during which synaptic connections are modified by visual experience. (20) Infants as young as 2 months of age show right hemispheric activation on positive emission tomography when exposed to a woman's face, and particular areas of the right hemisphere are timed to be in a plastic and receptive state at the very time when sensory information that emanates from faces is being attended to most intensely by the infant. (21) During synchronized face-to-face transactions, patterns of information emanating from the caregiver's face, especially of low visual and auditory frequencies, are processed by the infant's right hemisphere. Studies demonstrate that the development of the capacity to process information from faces efficiently requires visual input to the right (and not left) hemisphere during infancy. (22)

Over the first year, emotional communications embedded within mutual gazing are etched into developing right lateralized networks that are specialized for assessing familiar faces and gaze direction and for processing visual and auditory emotional signals. The right cerebral cortex is dominant for the infant's processing of individual faces, recognition of maternal facial expressions, and response to the mother's voice. Similarly, the mother's mature right hemisphere is faster than the left in appraising emotional facial expressions; responding to the positive aspects of facial expressions, visual stimuli, touch, and smell; and assessing visual or auditory emotional signals.

Other studies reveal that the response to an infant's cry, a fundamental attachment behavior, is accompanied an activation of the mother's right brain. These data support the idea that engrams related to emotional voices are imprinted more strongly on the infant's early maturing, more active right hemisphere. (23) With respect to tactile communications, most women tend to cradle infants on the left side of the body. This left-cradling tendency facilitates the flow of maternal affective signals into the infant's left ear and eye and processing in the developing right hemisphere, and the ensuing infant's auditory and visual communications are fed back to the center of emotional decoding in the mother's right hemisphere. (24) Researchers conclude that this left-cradling context allows for maximal somatoaffective feedback within the dyad and that "the role of the right hemisphere is crucial in relation to the most precious needs of mothers and infants." (25)

From a neurobiological perspective, "When the child is held and hugged, brain networks are activated and strengthened and firing spreads to associated networks; when the child is sung to, still other networks are strengthened to receive sounds and interpret them as song. The repeated appearance of the mother provides a fixation object as in imprinting." (26) The cortical and subcortical systems of the infant's right brain become tuned to dynamic self-organization upon perceiving certain patterns of exteroceptive social information, namely, the visual, auditory, and tactile stimuli emanating from the smiling, joyful, soothing, and calming face as well as the expressive body of a loving mother.

These imprinting experiences are "affectively burnt in" (27) developing limbic circuits in the infant's right brain, which are known to undergo extensive myelination in the first 18 postnatal months. Thus, at a fundamental level, the mother functions as a regulator of the infant's socioemotional environment, and her regulatory interactions play a critical role during the establishment and maintenance of developing emotion-processing limbic circuits. The spontaneous emotional communication that occurs within the attachment relationship has been described as "a conversation between limbic systems." Because the early maturing right hemisphere, which is deeply connected into the limbic system, is in a growth spurt at this time, attachment experiences specifically affect developing limbic and cortical areas of the right brain networks that are critical to self-regulation.

This research indicates that the mother functions in the short term as a regulator of the child's homeostatic alterations and in the long term influences the child's capacity to cope adaptively with the social-emotional environment. (28) Although the mother initially provides an external regulating mechanism for the infant's immature neurobiological pro-

cesses, by the end of the first postnatal year, the infant becomes self-regulating through the maturation of internal regulatory mechanisms entrained to the mother's stimuli. Current psychobiological models refer to representations of the infant's affective dialogue with the mother, which can be accessed to regulate its affective state. Studies are detailing how even subtle affect-regulating transactions alter activity levels permanently in the child's maturing brain. During the last 10 years, many studies have documented the enduring impact of maternal visual, vocal, and tactile emotional stimuli on the infant's brain development and on resulting emotional, social, cognitive, and regulatory capacities in later life. (11) (A detailed discussion of the relevant anatomy and physiology of the brain is presented in the appendix to this article.)

Secure Attachment, Optimal Right Brain Maturation, and the Psychoneurobiological Origins of Mental Health

In optimal interpersonal environments, coregulated emotional communications between the securely attached infant and the primary attachment object facilitate the self-organization and increased complexity of the infant's right brain. Following the child's attachment to the mother in the first year, the child forms another attachment in the second year to the father, allowing the child to have affect-attuning and arousal-regulating experiences with two different types of caregivers. As a result of this interaction with caregivers, the infant forms internal working models of attachment that are stored in right-lateralized nonverbal implicit-procedural memory. Security of attachment relates to a physiologic coding of an expectation that during times of stress, homeostatic disruptions will be set right. These interactive representations encode strategies of affect regulation and contain coping mechanisms for maintaining basic regulation and positive affect in the face of environmental challenge. The infant's ability to develop more complex self-regulatory coping capacities, to regulate stressful alterations of psychobiological state either interactively or autonomously, emerges out of its experiences with the social environment.

In all later interpersonal functioning, this right hemispheric representation of a working model of the attachment relationship, acting at levels beneath conscious awareness, is accessed to appraise, interpret, and regulate socioemotional information and guide future action in both familiar and novel interpersonal environments. For the rest of the life span, the right hemisphere that has been imprinted and organized by early relational experiences is dominant for the nonconscious reception, expression, communication, and regulation of emotion, essential functions for creating and maintaining social relationships, especially intimate ones. (29)(30)(31)(32) Studies suggest that attachment psychobiology and right brain neuropsychology represent the substrate of three other capacities that are critical to human interactions: trust, empathy, and moral development. (33)(34)(35)

Indeed, the right brain is dominant for the regulation of fundamental physiologic, endocrinologic, immunologic, and cardiovascular functions, thereby controlling vital functions that support survival and enable the organism to cope actively and passively with stress. A growing body of data underscores a strong association between alterations in maternal-infant interactions, early programming of the hypothalamic-pituitary-adrenal axis, pre- and postnatal critical periods of brain development, and adult health and disease. (36) This work is paralleled by studies linking attachment, stress, and childhood attachment (37)(38) with adult cortisol and cardiovascular function (39) and research showing that the right hemisphere plays a unique role for pain sensitivity and negative affect. (40) Assets or limitations of right brain survival functions, thus, affect not just "psychological" but also essential "psychobiological" capacities of coping with both emotional disturbance and physical disease. These regulatory capacities, significantly influenced by optimal attachment experiences, are critical indices of adaptive physical and mental health.

In addition to self-regulation, the right hemisphere is specialized for generating self-awareness and self-recognition and for the processing of "self-related material." (41)(42) Devinsky (9) posits an evolutionary role of the right hemisphere in the following adaptive functions: maintaining a coherent, continuous, and unified sense of self; identifying a corporeal image of self and its relation to the environment; distinguishing self from nonself; recognizing familiar members of a species as well as other familiar organisms, items, and places; recalling autobiographical information; appraising environmental reality; and emotionally understanding and reacting to bodily and environment stimuli. All of these critical adaptive functions are present by the second postnatal year (the end of the right brain growth spurt), and all are essential components of the earliest manifestation of mental health.

According to the unpublished manuscript of the Infant Mental Health Task Force of Zero to Three, National Center for Infant, Toddlers and Families, "Infant mental health is the developing capacity of the child

from birth to three years to experience, regulate, and express emotions; form close interpersonal relationships; and explore the environment and learn. . . Infant mental health is synonymous with healthy social and emotional development." The earliest expression of mental health reflects the adaptive or maladaptive functioning of the right brain, the neurobiological locus of the emotional self. (43)(44)

Although the right brain reorganizes later in life and retains plasticity, conditions affecting its initial stages of evolution have an enormous impact on its subsequent development. The postnatal maturation of limbic-autonomic circuits is influenced significantly by the primary caregiver's provision and regulation of social-emotional experiences within the attachment relationship. Neuroscience now reveals that at the most fundamental level, regulated attachment experiences facilitate the brain's major regulatory systems, located in the right brain. However, studies also show that unrepaired and chronic stressful dysregulating interactions within the early social environment lay the groundwork for an insecure attachment, right brain dysfunction, limbic-autonomic deficits, and the development of a predisposition to later psychiatric and psychosomatic disorders.

The principle that early disruption of the mother-infant attachment relationship has a negative impact on brain plasticity and predisposes to later psychopathology is well established. (10)(45)(46)(47)(48)(49)(50) Helmeke and associates (51) concluded, "Positive (formation of emotional attachment) or negative (eg, maternal separation or loss) emotional experience may carve a permanent trace into a still developing neuronal network of immature synaptic connections, and thereby can extend or limit the functional capacity of the brain during later stages of life." (See *Affect Dysregulation and Disorders of the Self* (11) for an extensive discussion of the neurobiology of psychopathogenesis).

The increasing appreciation of the profound and indelible impact of early interpersonal relationships on the psychological, physiologic, and neurobiological trajectory of the self over all stages of life substantially alters our view of human infancy. In the middle of the last century, the pediatrician-psychoanalyst Donald Winnicott asserted that there is no infant without the mother. (52) This developmental psychological conception is mirrored in the previously mentioned developmental neurobiological principle that "the self-organization of the developing brain occurs in the context of a relationship with another self, another brain." (7) This other brain is the right brain of the primary caregiver, the mother. Although controversies have existed in the past, a large and consistent body of developmental neuroscience research across both human and animal species confirms the central role of the early relationship with the mother in the neurobehavioral development and, therefore, future social-emotional and stress-regulation capacities of the developing individual. (25)(28)(45)(46)(53)(54)(55)(56)(57)(58)(59)

There is an intense interest in neuroscience in the enduring impact of early "enriched experience" on brain development in the first 18 postnatal months and in the applications of this knowledge to child development. These studies indicate that enriched experiences "are especially effective early in life and they set the basis for later use and maintenance of the brain and of ability." (60) In the past, an "enriched environment" has been defined narrowly as a complex physical environment, and the reputed impact of early exposure was on cognitive development. It now is clear that for optimal brain development, the infant also needs to interact with an enriched social environment. The spectrum of regulated affective transactions within a psychobiologically attuned mother-infant attachment relationship defines an enriched environment more correctly—one that has a long-term impact on emotional development and the essential capacity of self-regulation.

In accord with these conceptualizations, a very recent National Institute of Child and Human Development study on the mother-child relationship and affect dysregulation concluded, "Self-regulation in infancy is best conceptualized as a quality of the infant-caregiver relationship, rather than a characteristic of the infant alone." (61) The authors cited a large body of data that "emphasize the importance of the child's relationship with the primary caregiver as central to understanding the developmental processes leading from early affective arousal and attention control to later functioning. . . Children's inability to control negative affect in early interactions with their caregivers may forecast continuing difficulties with affective regulation across multiple contexts."

Psychobiological markers that assess attachment relationships, regulation of affect, the right brain, and infant mental health need to be included in the diagnostic armamentarium of the practicing pediatrician. This information allows the clinician to understand the system of nonverbal communication and interactive regulation that lies at the core of the mother-infant relationship. To assess the social and emotional capacities of the nonverbal infant and the status of the nonverbal communications

within the attachment dyad, the pediatrician must use clinical skills that involve her or his subjective right brain as well as objective left brain. The principles of regulation theory that apply to the mother-infant relationship also apply to the clinician-patient relationship. (10)(12) According to Adler, (62) the art of the doctor-patient relationship, which involves the physician's empathy and the capacity for responsive listening, "entails establishing the same kind of person-to-person attunement that is essential to the development of the newborn (Shore, 1994)." Psychobiological markers that assess attachment relationships, regulation of affect, the right brain, and infant mental health need to be included in the diagnostic armamentarium of the practicing pediatrician. (See the Table for a schematic of clinical observations of affect regulation and right brain development.)

Summary

Recent interdisciplinary data on attachment, affect regulation, and the right brain can be applied directly to clinically relevant models of the earliest manifestations of normal and abnormal social and emotional development. Adaptive infant mental health, an outcome of optimal attachment experiences, can be defined as the earliest expression of efficient and resilient right brain strategies for regulating both negative and positive affective states and for coping with novelty and stress, especially interpersonal stress. (43) The formation of an increasingly complex right brain system for communicating emotion allows the developing individual to switch internal, bodily based affective states in response to perceived changes in the external social environment via autoregulation or interactive regulation, thus maintaining a cohesive sense of self in both autonomous or interconnected contexts.

On the other hand, maladaptive infant mental health is manifest in a poor right brain capacity to enter into emotional communications with others, prolonged frequent and intense episodes of affect dysregulation, a fragile self system, and an inability to adapt to demands of the dynamically changing social environment in a timely manner. (48) The former is a resilience factor for coping with the psychobiological stressors inherent in social interactions; the latter is a risk factor for interruptions of developmental processes and a vulnerability to the coping deficits that define a predisposition to later-forming psychopathology. These conceptions directly relate to what the American Academy of Pediatrics terms "the attainment of optimal physical, mental, and social health for all infants" and thereby the primordial expression of health in "children, adolescents, and young adults."

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Table. Schore's Model of Affect Regulation and Right Brain Development

	Infant Context	Mother Context	Interactive Context Right Brain to Right Brain
RIGHT BRAIN COMMUNICATION PROCESSES			
VISUAL/FACIAL Regulated Response	• Orients, explores, gazes at face of mother and others, seeks eye contact. • Displays bright, wide-eyed facial expressions. • Uses a wide range of affective expressions. • Resting quiet-alert state of pleasant facial expressions.	• Responds (attunes) to infant's cues with variety of affectively expressive facial expressions (eye contact, smiling, pleasant facial expressions).	• Dyadic visual-affective arousal regulation. • Each member of dyad focuses gaze upon the other, engaging in mutual eye contact, smiling, bright facial expressions. • Interpersonal resonance amplifies positive states in both.
Stress Response	• During relational stress, transiently avoids orienting, exploring, or gazing at mother's face or engaging in eye contact.	• Flat, absent, fear-inducing, or incongruent facial expressions (laughing when infant is distressed).	• One breaks off mutual gaze and/or eye contact. • Dyad transiently out of sync (misattuned); acute dyadic stress. • *Absence or avoidance of eye contact by either mother or infant may be a significant indicator requiring further investigation.*
VOCAL TONE AND RHYTHM Regulated Response	• Turns towards mother's voice. • Uses inviting/playful tone in response (cooing, babbling).	• Vocalizes soothing responses with varied tones and rhythms. • Modulates tones and rhythms of voice to infant's psychobiological state.	• Dyadic auditory-affective arousal regulation. • Matches or imitates each other's vocal tones and rhythms.
Stress Response	• During relational stress, transiently turns away from mother's voice. • Uses distressed tone (crying) in response or is nonresponsive.	• Uses discordant, harsh, loud, or unmodulated tone and rhythm of voice or does not use vocalizations in response to infant's emotional communication. • Does not vocalize or mirror (match) infant's vocalizations.	• One uses discordant tone while the other is silent or both are using distressed or discordant tones. • *Nonresponsivity or turning away from mother's voice may be a significant indicator requiring further investigation.*
GESTURAL/POSTURAL Regulated Response	• Moves limbs and body evenly and fluidly, relaxed posture, reaches and turns toward other or novel social stimulus.	• Approaches to soothe, manipulate, or maneuver infant gently and cautiously. • Responds to and interprets social bodily based gestures.	• In intimate physical context, dyad's rhythmic matching allows bodies to cradle/mold into other. • In social referencing late in first year, gestures become purposeful and synchronized, promoting intersubjective engagement.

(continued)

Table. Schore's Model of Affect Regulation and Right Brain Development (continued)

	Infant Context	Mother Context	Interactive Context Right Brain to Right Brain
Stress Response	• In socially stressed contexts, moves limbs unevenly and/or frantically. • Fails to reach out, averts head, turns body away, stiffens or arches body to mother's touch.	• Approaches infant too quickly or responds to infant in threatening or fearful manner. • Handles awkwardly or roughly. • Misinterprets infant's gestures or does not attempt to soothe, respond, or interpret gestures and body movements.	• Infant continues or increases distressed gestures and postures and is unresponsive to mother's efforts. • Mother increases rough/awkward gestures/postures. • Mother continues to misinterpret infant's gestures/body movements. • Dyad becomes frustrated or ceases/fails to attempt to soothe and comfort interactively.
RIGHT BRAIN AFFECT PROCESSING			
POSITIVE AFFECT PROCESSING			
Regulated Response	• High, positive arousal. • Enjoyment-joy, interest-excitement. • Vitality expressed freely.	• Happy demeanor; responsive to, supportive of, and matching of infant's affect and positive arousal.	• Mutual delight. • Mother or infant leads affective interaction while other follows. • Non-overwhelming and turn-taking behaviors. • Dyadic amplification of positive arousal in relational play.
Stress Response	• Hyperaroused/overstimulated or hypoaroused/understimulated.	• Incongruent happy demeanor to infant's distressed cues or sad demeanor to infant's positive cues. • Continues to fail to create regulated, positive arousal stimuli for infant. • Low frequency of play behavior.	• Mismatched (misattuned) arousal states. • One or both hyperaroused/overstimulated or one is in positive arousal state while the other is hypoaroused/understimulated or hyperaroused/overstimulated. • Overwhelmed dyad.
NEGATIVE AFFECT PROCESSING			
Regulated Response	• Fussy, moody affect expressed freely. • Resilience.	• Able to tolerate and express sadness, anger, fear in self and infant while seeking to interact appropriately. • Participates in interactive repair.	• Mutual attuning to disquieting stimuli or condition.
Stress Response	• Withdraws or is nonresponsive or becomes agitated, frustrated, or fearful when experiencing sensations of distress (dysregulated states). • Increasing intensity and duration of either state precludes infant's quick response to soothing attempts and return to regulated state.	• Unable to tolerate own negative feelings and responds inappropriately (expresses anger, irritation, or frustration or withdraws and is nonresponsive toward infant). • Poor capacity for interactive repair.	• Mutual frustration. • Mother cannot or does not soothe infant and repair negative affect: dyad remains in distressed state.

	Infant Context	Mother Context	Interactive Context Right Brain to Right Brain
RIGHT BRAIN REGULATION			
INTERACTIVE REGULATION	• Expresses and recognizes affective facial expressions, vocalizations, and gestures. • Infant seeks out mother to coregulate inner state of being.	• Responds with arousal/regulating facial expressions, vocalizations, and gestures. • Mother seeks to affect infant's inner state of being.	• Each member of dyad contingently responds to other's facial expressions, vocalizations, and gestures (right brain to right brain) • Mother and infant interactively seek attunement. • Frequent episodes of interactive play.
AUTOREGULATION	• Self-soothing behaviors (sucks finger/pacifier, rocks body, holds soft object). • Self-created solutions for regulating inner state of being.	• Self-calming behaviors (deep breaths, self-talk). • Mother lets infant struggle with distress briefly and then regulates (assists in autoregulation).	• Each member of dyad remains calm in presence of other. • Each regulates own state of being autonomously.
RIGHT BRAIN DYSREGULATION			
INTERACTIVE DYSREGULATION	• Averts gaze, becomes agitated by sounds and gestures. • Startles to parent. • Habitually disconnects from mother's attempts to coregulate while inner state escalates. • Sense of safety threatened by interaction.	• Frequent angry, hostile facial expressions, harsh tone and uneven rhythms, threatening gestures. • Does not look at the infant or unresponsive "dead face." • Repeatedly fails to respond to infant's affective struggle despite infant's escalating inner distress.	• Mutual arousal dysregulation. • Individually or dyadically ignores cues of other; dyad fails to collaborate in regulating infant's inner need state. • Inconsolable infant may lead to mother's negative feelings toward him/her and diminish mother's confidence in her being a "good enough" mother.
AUTODYSREGULATION	• Crying, arching, flailing, and vomiting; or blank stare, limp, motionless. • Infant repeatedly fails to self-regulate inner state, becoming overwhelmed, eventually exhausted and withdrawn. • Dissociates to maternal stimuli. • Chronic sense of threat or lack of sense of safety.	• Irritable, threatening, intrusive, and rough or flat affect, unresponsive. • Disregards infant's ability to auto-regulate by quieting or stimulating self. • Dissociates to infant's stimuli.	• Agitated or withdrawn in presence of other. • Both fail to allow infant to enlarge his/her capacity to self-regulate affect. • No relational or intersubjective context.

Appendix. Anatomy and Physiology of Attachment and Affect Regulation

In his initial outline of attachment theory, Bowlby hypothesized that a succession of increasingly complex regulatory systems involving the limbic system and brain arousal areas mediates attachment processes. The neuroscience literature now refers to the "rostral limbic system," a hierarchical sequence of interconnected limbic areas in the amygdala, anterior cingulate, insula, and orbital cortex, and a "circuit of emotion regulation" consisting of the amygdala, anterior cingulate, and orbital frontal cortex. Based on the principle of caudal-to-rostral brain development, I have offered a model of the early experience-dependent maturation of the limbic system and proposed a sequence of regulatory systems that are imprinted by more complex attachment communications and evolve over the first 2 years of human infancy. (1)(2) The optimal formation of these brain areas essential to the child's emotional development depends on the interactive regulation embedded within the attachment communications of the mother-infant relationship.

At birth, only the amygdala, a primitive subcortical limbic regulatory system that appraises crude information about external stimuli and modulates autonomic and arousal systems, is online. The right amygdala processes olfactory stimuli within the mother-perinatal infant relationship and mediates the infant's recognition of the mother's scent as well as the mother's recognition of the neonate through olfactory cues. At 8 weeks, a critical period for the development of the anterior cingulate commences, allowing this system to regulate play and separation behaviors, laughing and crying vocalizations, face representations, and the modulation of autonomic activity. The first year also is a critical period of experience-dependent maturation of the right insula, a structure within the temporal lobes that is involved essentially in the subjective awareness of inner body feelings and emotionality, and the right parietal cortex, a posterior cortical area involved in the representation of the physical self and the ability to distinguish self from others.

By the last quarter of the first postnatal year, the orbital (ventromedial) areas of the frontal lobes enter a critical period of growth that continues through the middle of the second year. The orbitofrontal cortex, the hierarchical apex of the limbic system, acts at the highest level of control of behavior, especially in relation to emotion, and is identical to Bowlby's control system of attachment. I have suggested that in mutual gaze transactions, the mother is downloading programs from her limbic system into the child's developing limbic system. A very recent fMRI study by Nitschke and colleagues of mothers viewing a photograph of their own infants showed maximal brain activation in the mother's orbitofrontal cortex, especially on the right side. (3) These authors concluded that this cortex plays a critical role in the representation of attachment-related positive affect, as described by Bowlby, that it linearly tracks the intensity of positive emotions underlying maternal attachment, and that individual variations in orbitofrontal activation to infant stimuli reflect an important dimension of maternal attachment.

Other studies demonstrate that the right prefrontolimbic areas play a primary role in the appraisal of biologically meaningful exteroceptive and interoceptive self-related information and in the integration of internal physiologic states with salient environmental cues, processes central to the attachment mechanism. This right cerebral hemisphere is critically involved in regulating the hypothalamic-pituitary-adrenal (HPA) axis and in activating physiologic stress responses. (4) More than any other area of the human prefrontal lobes, the right orbitofrontal cortex, which plays an executive control function for the entire right brain, is linked most directly to the brain's stress regulatory system. (5) Recall, the regulation of stressors in social relationships, modifies prefrontal maturation, and in this manner a secure attachment facilitates the transfer of regulatory capacities from caregiver to infant. Lyons and colleagues state, "Theories of human development suggest that stressful experiences in social relationships modify prefrontal maturation (Schore, 1996)" and demonstrate that conditions that affect early maternal variability in infancy produce "significant differences in right but not left adult prefrontal volumes, with experience-dependent asymmetric variation most clearly expressed in ventral medial cortex measured in vivo by magnetic resonance imaging." (6) Thus, on a fundamental level, the attachment relationship between the child and primary caregiver is formative because it promotes the development of the brain's major self-regulatory mechanisms.

More specifically, the attachment relationship mediates the dyadic regulation of both positive and negative emotion via the maternal interactive regulation of the infant's postnatally developing autonomic nervous system (ANS). Optimally regulated communications embedded in secure attachment experiences imprint the connections between the postnatally maturing central nervous system limbic system that processes and regulates social-emotional stimuli and the ANS that generates the somatic aspects of emotion. A growing body of work reveals that the right hemisphere is deeply connected into the

ANS and that it, more so than the left, controls both sympathetic and parasympathetic responses. (7) The hypothalamus, the head ganglion of the ANS, is right lateralized, and the hypothalamic nuclei are considerably larger on the right side of the human brain. This hemisphere is dominant for the production of corticotropin-releasing factor and the glucocorticoid cortisol, the neurohormones that mediate stress coping responses. Convincing evidence shows that the infant's relationship with the mother regulates the development of the HPA axis, (8) that neonatal social behavior associated with the HPA axis increases right hemisphere dominance, (9) and that perinatal distress leads to a blunting of the stress response in the right (and not left) prefrontal cortex that is manifest in adulthood. (10)

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As the field of adolescent neuroscience develops, the application of findings to interventions will face an important challenge of how to understand the complex relationships between developmental biology and the environments in which adolescents live. Much of the neuroscientific evidence is developed in the global North, and more information is needed to reflect the diverse experiences of adolescents around the world, including in harsh situations of war, conflict, chronic stress and malnutrition. These relationships facilitate optimal brain development and stimulate the infantâ€™s curiosity to explore and learn. The importance of experiences within the attachment relationship for infant behavioural and emotional regulation, and the neurobiological mechanisms underlying the process of attachment, has been a clinical and research focus. Nurturing, contingent, stable, and predictable early experiences promote healthy brain development and the optimal regulation of physiological stress regulation systems.Â Back to Basics: Attachment, affect regulation, and the developing right brain: Linking developmental neuroscience to paediatrics. Pediatrics in Review, 26, 204-217. Shonkoff, J. 2010. Building a New Biodevelopmental Framework to Guide the Future of EarlyChildhood Policy. See more ideas about neuroscience, adverse childhood experiences, trauma.Â He was interviewed by Julie Beem of the Attachment Trauma Network (ATN). Dr. Greene is the author of The Explosive Child and Lost at School, Lost & Found and Raising Human Beings . He's the originator of the Collaborative and Pro-Active Solutions (CPS) model .Â Memories of trauma are unique because of the way our brains and bodies respond to threat. What Is Mental Health Improve Mental Health Anxiety Coping Skills Stress And Anxiety Growth Mindset Activities Cognitive Therapy Intrinsic Motivation Mindfulness Activities Social Emotional Learning. Exaggerated Thoughts That Can Cause Adolescents to Misperceive Reality | KQED. Reviews the book, Neuroscience of cognitive development: The role of experience and the developing brain by Charles A. Nelson, Michelle de Haan, and Kathleen M. Thomas (see record 2006-09288-000). The goal of this book is to provide a state-of-the-art introduction to the neural bases of cognitive development.Â Back to Basics Attachment, Affect Regulation, and the Developing Right Brain: Linking Developmental Neuroscience to Pediatrics. Article. Jul 2005. Allan N Schore. Editor's Note: This article is a departure from our usual review in that it discusses new frontiers in the correlation of brain, mind, and emotions in developing children as well as areas of collaboration between pediatrics and sister disciplines. Mandatory Readings: Back to Basics: Attachment, Affect Regulation, and the Developing Right Brain: Linking Developmental Neuroscience to Pediatrics. Goals & Objectives. Knowing how to counsel parents effectively rests on understanding their concerns, hearing their stories and becoming more facile observers of the parent, the child and their interactions. What better place than in the laboratory (the well-child visit) before you? During this rotation, on as many occasions as you can, go somewhere where parents and kids hang out (supermarkets, malls, playgrounds, etc.) On the enclosed form, note