Development and Psychopathology, **14** (2002), 477–498

Printed in the United States of America
DOI: 10.1017.S095457940200305X

Self-regulatory processes in early personality development: A multilevel approach to the study of childhood social withdrawal and aggression

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Abstract
Self-regulatory processes are believed to be critical to early personality and behavioral adjustment. Such processes can be observed on multiple levels, including the physiological, attentional, emotional, cognitive, and interpersonal domains of functioning. Data from several longitudinal studies suggest links between early temperamental tendencies such as behavioral inhibition and frustration tolerance, and regulatory developments at the levels of physiological, attentional, and emotional regulation. Deficits in these particular levels of self-regulation may underlie childhood social withdrawal and aggression. Significant gaps remain in our knowledge of the pathways to disordered behavior and the role that self-regulation plays in such pathways. Suggestions are made for the ways in which future longitudinal studies might address these gaps.

During the last several years, the discipline of developmental psychopathology has produced a corpus of research underscoring the importance for social development and behavioral adjustment of individual differences in personality (Calkins & Dedmon, 2000; Calkins, Fox, & Marshall, 1996; Eisenberg, Fabes, Bernweig, Karbon, Poulin, & Hanish, 1993; Eisenberg, Fabes, Guthrie, Murphy, Maszk, Holmgren, & Suh, 1996; Eisenberg, Fabes, Nyman, Bernzweig, & Pinuelas 1994; Eisenberg, Murphy, Maszk, Smith, & Karbon, 1995; Fox, Schmidt, Calkins, Rubin, & Coplan, 1996; Gunnar, Tout, deHaan, Pierce, & Stansbury, 1997; Rubin, Coplan, Fox, & Calkins, 1995). Important in this work is the role that various dimensions of personality or temperament play in the unfolding of multiple possible pathways to adaptive or maladaptive adjustment. A theoretical perspective that is well suited to guiding the empirical investigation of such pathways may be found in the field of developmental psychopathology.

A developmental psychopathology perspective suggests that there are multiple contributors to maladaptive and adaptive outcomes, that these contributors may interact in various ways within different individuals, and that the consequences for development are multiple pathways to disordered behavior and/or multiple variants of outcome from individual causative factors (Cicchetti, 1984, 1993; Cicchetti & Rogosch, 1996; Sroufe & Rutter, 1984). Cicchetti and Rogosch (1996) and Richters (1997) described these perspectives as multifinality and equifinality. Multifinality refers to the possibility of multiple or heterogeneous outcomes as a result of similar puta-

This research was supported by National Institute of Health grants to Susan D. Calkins (MH 55584 and MH 58144) and Nathan A. Fox (HD17899). Thanks to Laura Lomax and Susan Dedmon for input on this manuscript.

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tive etiological factors. Thus, early neglect may result in a number of different maladaptive outcomes, or it may, in some instances, have no obvious harmful effect. Equifinality refers to the possibility that similar outcomes may be the result of multiple and nonoverlapping developmental trajectories. So, for example, aggressive behavior in childhood may be a consequence of a temperamental disposition toward such behavior or a function of exposure to negative and coercive parenting. Such a perspective emphasizes the importance of conducting longitudinal investigations of the multiple forces that may both influence, and be influenced by, early contextual, familial, or individual difference factors. This perspective also stimulates an interest in resilience, or the role of protective factors, and an examination of those features of either the child or the environment that may alter the developmental pathway such that adjustment, rather than maladjustment, is possible (Luthar, Cicchetti, & Becker, 2000; Masten, Best, & Garmezy, 1990; Rutter, 1987). A developmental psychopathology perspective advocates an organizational view of development; thus, multiple factors are considered in the context of one another, rather than in isolation (Cicchetti & Rogosch, 1996; Cicchetti & Schneider–Rosen, 1984). Finally, a developmental psychopathology theoretical approach is compatible with an empirical approach that focuses on extreme groups or types of individuals in order to specify developmental profiles (Bergman & Magnusson, 1997; Kagan, 1997a).

In applying the developmental psychopathology perspective to the study of early personality, researchers have sought to identify the multiple dimensions of child functioning and environmental influences that may be implicated in the acquisition of the skills and abilities necessary for successful social interaction and behavioral adaptation. However, multiple factor approaches to the study of personality development and behavioral adjustment have taken different forms. One approach has been to classify into discrete, yet broad, levels the multiple forces that may act on an individual's development (Hinde, 1992; Rubin, 1998). In such an approach, for example, the individual, interactions between individuals, relationships among individuals, group processes, and the influence of the society or culture would be considered among the multiple levels that may affect the developmental outcome. These levels may be analyzed as discrete factors and as reciprocally interacting forces affecting one another across development (Hinde, 1992). Another approach is to consider the multiple levels that might exist *within* these broad factors. Thus, for example, relationships may be viewed as being hierarchically organized across development with face to face interactions building into attachments and attachments building into social interactional skills. Similarly, the individual may be regarded as a self-regulating system that consists of multiple, increasingly differentiated levels and can be studied by examining simultaneously the physiological, emotional, behavioral, and social processes that contribute to adaptive regulatory behavior (Posner & Rothbart, 2000). Recent empirical work suggests that the self-regulatory system is implicated in personality, social, and cognitive development (Bronstein & Suess, 2000; Calkins & Dedmon, 2000; Fox et al., 1996; Rothbart & Jones, 1998). Indeed, Posner and Rothbart argued recently that understanding the self-regulatory system is critically important to our understanding of development and psychopathology (Posner & Rothbart, 2000).

In our work, we seek to understand the multiple levels of self-regulation that emerge and develop over the course of infancy and childhood and how those levels affect personality development and behavioral adjustment. Indeed, most recent approaches to the study of individual differences in personality during infancy and early childhood have conceptualized these differences in terms of variability in temperamental reactivity and self-regulation (Calkins & Johnson, 1998; Fox, Henderson, & Marshall, in press; Gunnar, Porter, Wolf, Rigatuso, & Larson, 1995; Posner & Rothbart, 2000; Rothbart & Derryberry, 1981; Stifter & Braungart, 1995). Variations among children can be observed in the latency, intensity, frequency, and duration of

emotional and behavioral reactions and in the attentional and behavioral strategies used to manage such reactions (Rothbart & Derryberry, 1981). In addition, behavioral manifestations of emotion, experience, attention, and emotion or behavior management have underlying physiological substrates (Calkins & Dedmon, 2000; Calkins et al., 1996; Fox, 1989; Stifter & Fox, 1990).

During infancy and early childhood, children gradually acquire the self-regulation skills and strategies necessary to cope with a variety of developmental challenges (Cicchetti, Ganiban, & Barnett, 1991; Kopp, 1982, 1989; Tronick, 1989). In infancy, the child's success at regulation depends heavily on the parent's awareness, flexibility, and responsivity to emotional expression and the child's need for intervention. During toddlerhood, the ability to use self-regulating behaviors becomes critical as the child gains independence, control, and an identity separate from that of the caregiver. It is important that recent research on the self-regulation of emotion demonstrates quite convincingly that the display of affect and affect regulation are powerful mediators of interpersonal relationships and socioemotional adjustment during the first few years of life (Calkins, 1994; Calkins & Fox, 1992; Cicchetti et al., 1991; Malatesta, Culver, Tesman, & Shephard, 1989; Rothbart, 1989; Thompson, 1994).

In this paper, we describe how a multilevel theoretical approach that specifies a multimethod empirical approach, including the observation of behavior and assessment of physiological correlates to behavior, informs our understanding of the development of self-regulation and its role in the development of early adjustment problems. Specifically, we argue that a multiple level approach to the study of self-regulation may explain both the development of childhood social withdrawal and aggression and the individual pathways to these disorders that have been observed. We highlight areas of our own research that provide support for such a view, discuss the difficulties inherent in such an approach, and identify the future directions that research must take to further our understanding of the role of the self-regulatory system in personality development and early child functioning.

Self-Regulatory Developments in Infancy and Early Childhood

In defining self-regulation, Rothbart and colleagues (Rothbart & Derryberry, 1981; Rothbart & Posner, 1985) focused on a general definition that encompasses multiple levels of the analysis of regulation. In this approach, self-regulation is defined as the child's ability to modulate behavior according to the cognitive, emotional, and social demands of a particular situation (Posner & Rothbart, 2000) or, even more simply, as processes by which one system controls the reactivity of another system (Derryberry & Reed, 1996). The initial responses of the infant are characterized by reactions to sensory stimuli of different qualities and intensities. This reactivity is thought to be present at birth and to reflect a relatively stable characteristic of the infant (Rothbart, Derryberry, & Hershey, 2000). Regulatory processes begin to develop prenatally and evolve into a more sophisticated and self-initiated process over the course of the toddler, preschool, and school years (Posner & Rothbart, 2000; Rothbart & Jones, 1998). Thus, for example, infants may differ initially in their threshold to respond to visual or auditory stimuli of a certain intensity (e.g., Calkins, Fox, & Marshall, 1996). Over the course of development, the child's increasing capacity to regulate motor and affective behavior, first as a result of a supportive caregiving context and later as a function of voluntary and effortful control, moderates these initial reactive responses. Much of the development of self-regulation is a result of increasing control over attentional processes, as well as enhanced inhibitory control over motor behavior (Fox, Henderson, Rubin, Calkins, & Schmidt, 2001; Kochanska, Coy, & Murray, 2001; Ruff & Rothbart, 1996). During the second and third years of life, children begin to gain control over impulses and actions that are mostly activated by the situation. During the preschool years, children become aware of the factors that affect their

attention, such as motivation and noise (Miller & Zalenski, 1990). It is important that each of these skills will support the emergence of the kind of independent and adaptive behavioral functioning that is necessary for the child to make a successful transition to the school and peer environment. It is important to note, however, that these normative developments do not preclude the possibility that both reactivity and regulation may be influenced by environmental events and alter the trajectory of a child's development (Cicchetti & Rogosch, 1996).

A key construct in Rothbart's theory of temperament is effortful control, defined as the ability to inhibit responses to stimuli in the immediate environment while pursuing a cognitively represented goal (Rothbart & Posner, 1985). As a temperamental dimension, effortful control refers to a special class of self-regulatory processes that develop with the maturation of attentional mechanisms, particularly the anterior attention system (Posner & Rothbart, 1992). Although it is believed that effortful control begins to emerge at the end of the first year of life, its development continues at least through the preschool years. Thus, the system of regulation that emerges over time becomes more differentiated, more voluntary, and more systematically deployed. Nevertheless, this system is relatively slow to develop and its development, although influenced by temperamental reactivity, is likely a function of other factors as well.

Inherent in Posner and Rothbart's theory is the view that neurobiological systems underlie the developments in behavioral regulation (Posner & Rothbart, 2000). Thus, one way to conceptualize the self-regulatory system is to describe it as adaptive control that may be observed at the level of physiological, attentional, emotional, behavioral, cognitive, and interpersonal, or social processes. Control at these various levels emerges, at least in primitive form, across the prenatal, infancy, toddler, and early childhood periods of development. Importantly, though, the mastery of earlier regulatory tasks becomes an important component of later competencies. Thus, for example, the control of physiological arousal, which is achieved during early infancy and underlies mastery of state regulation and control of sleep–wake cycles, eventually becomes integrated into the processes of attention engagement and disengagement (Porges, 1996; Richards, 1985, 1987). Moreover, attentional control becomes integrated into emotional and behavioral regulation (Belsky, Friedman, & Hsieh, 2001; Rothbart, Posner, & Boylan, 1990; Sethi, Mischel, Aber, Shoda, & Rodriquez, 2000). In our view, these early developing levels of regulation—physiological, attentional, and caregiver-supported emotional regulation—play a critical role in very early personality and social behavior, and these early emerging behaviors will be reciprocally involved in the development of more complex levels of regulation, such as those involved in behavioral control, interpersonal processes, and metacognitions (Cole, Michel, & Teti, 1994; Stifter, Spinrad, & Braungart–Rieker, 1999).

Self-regulation at the physiological level

Traditionally, the purpose of psychophysiological measures in developmental research was to provide a window on processes that were difficult to observe in other ways. Research on learning with preverbal infants, for example, was one type of work that was traditionally conducted with psychophysiological measures. Current approaches to developmental psychophysiological work emphasize that certain underlying physiological processes and functioning may play an important role in the etiology of early regulatory behaviors (Fox, 1994; Fox & Card, 1999), and they are believed to underlie functioning in many domains of infant and child behavior (Bronstein & Suess, 2000; Fox, 1994; Porges, 1996). Three primary types of measures are used to study relations between physiology and self-regulatory behavior to a variety of elicitors: measures of heart rate (HR), brain electrical activity, and adrenocortical activity. Excellent reviews of the use of these three measures in both the adult and child literature can to be found in Fox, Schmidt, and Henderson (2000), Porges (1991), Gunnar (1989), and Stansbury and Gunnar (1994).

One physiological measure that was recently utilized in the study of infant emotional regulation and social development is the ongoing electroencephalogram (EEG). The EEG is low-level electrical activity recorded off the scalp. First noticed by Berger (1929), the EEG has been routinely recorded in adults during cognitive tasks and situations designed to elicit different emotions. With the advent of powerful and fast computers, it became possible to both collect large amounts of EEG data, sample the signal quickly, and perform a spectral analysis of the signal, decomposing it into energy at different frequency bands. Berger (1929) had noticed that the energy in the EEG decreased when patients were attending to the environment. This phenomenon, later detailed by Lindsey and Wicke (1974), is known as alpha desynchronization or alpha blocking. Greater desynchronization (decreased energy in a frequency band) is associated with increased activation. Researchers interested in the pattern of activation between the right and left hemispheres compute ratio scores of the difference in power or energy between the two hemispheres. These ratio or difference scores present relative differences in power and a score that reflects the degree to which one hemisphere or region in a hemisphere exhibits greater activation than a homologous region. There is an extensive literature on EEG asymmetry patterns during verbal versus spatial tasks (Davidson, Chapman, Chapman, & Henriques, 1990; Davidson, Jackson, & Kalin, 2000) and during the expression and perception of different emotions (Davidson, 1984; Fox & Davidson, 1986).

Fox speculates that a stable resting pattern of frontal EEG asymmetry may reflect an underlying "trait" disposition for the motivational states of approach or withdrawal and that such motivational states may facilitate adaptive regulatory behavior (Fox, 1994; Fox et al., 1996; Fox et al., 2001). Thus, lateralized brain function serves as the foundation, much like temperamental reactivity. Superimposed on this foundation are processes such as attention, which function to provide competencies to the child for adaptive emotion regulation. It is important to distinguish between the notion of lateralized brain systems involved in basic underlying motivational behaviors and those brain systems involved in cognitive processes such as verbal mediation, analytical abilities, monitoring, and inhibition of prepotent responses, all of which may be directly tied to emerging regions of the frontal cortex. Thus, for example, the orbitofrontal cortex appears to be important in decision making processes involving emotion, regions of the anterior cingulate are implicated in error detection and attention, and the dorsolateral frontal cortex appears critical for working memory (Davidson, 2000). These competencies (decision making, error detection, working memory) are all involved in adaptive emotion regulation and are a function of the prefrontal cortex. Emotional control is a consequence of the dynamic interaction of the frontal regions (Fox, 1994).

With respect to cardiac measures that may be used to index regulation, recent research suggests that HR variability may play a crucial role. Porges (1991, 1996) proposed a hierarchical model of self-regulation that assumes that complex behavioral regulation is dependent on appropriate physiological regulation, as measured by high frequency variability or vagal tone. Vagal tone, a component of parasympathetic control, can be measured as the amplitude of respiratory sinus arrhythmia (RSA), as quantified from beat to beat heart period data. The vagus is a cranial nerve that runs from the brain stem at the nucleus ambiguous to various body organs, which include the heart and digestive system, and promote dynamic feedback between the brain centers and the organs that regulate homeostasis. This coordinating role has led researchers to describe RSA not only as an index of neural control of the heart but also as an assessment of underlying regulatory abilities in mammals (Doussard–Roosevelt, Porges, Scanlon, Alemi, & Scanlon, 1997).

High resting RSA is associated with appropriate emotional reactivity (Stifter & Fox, 1990) and good attentional ability (Richards, 1985, 1987; Suess, Porges, & Plude, 1994). Several studies have linked high RSA in newborns with favorable developmental outcomes, suggesting that it may be an important

physiological component of appropriate engagement with the environment (Hoffheimer, Wood, Porges, Pearson, & Lawson, 1995; Richards & Cameron, 1989). The suppression of RSA during demanding tasks may reflect physiological processes that allow the child to shift focus from internal homeostatic demands to demands that require internal processing or the generation of coping strategies to control affective or behavioral arousal. Thus, the suppression of RSA is thought to be a physiological strategy that permits sustained attention and behaviors indicative of active coping that are mediated by the parasympathetic nervous system (Porges, 1991, 1996; Wilson & Gottman, 1996). Recent research indicates that the suppression of RSA during challenging situations is related to better state regulation, greater self-soothing, and more attentional control in infancy (DeGangi, DiPietro, Greenspan, & Porges, 1991; Huffman, Bryan, del Carmen, Pederson, Doussard–Roosevelt, & Porges, 1998); fewer behavior problems and more appropriate emotion regulation in preschool (Calkins, 1997; Porges, Doussard–Roosevelt, Portales & Greenspan, 1996), and sustained attention in school-age children (Suess et al., 1994). The extension of these research findings is that, although the ability to suppress RSA may be related to complex responses involving the regulation of attention and behavior, a deficiency in this ability may be related to early behavior problems, particularly problems characterized by a lack of behavioral and emotional control (Porges, 1996; Wilson & Gottman, 1996).

Regulation at the attentional level

The capacity for attentional self-regulation begins to emerge and mature toward the end of the first year. However, the development of attention continues throughout the preschool and school years (Rothbart, 1989). Individual differences in the ability to voluntarily sustain focus, shift attention, initiate actions, and inhibit actions are believed to be early behavioral reflections of an emerging system of effortful control (Adahi & Rothbart, 1994).

Although newborn attention is selective, it is controlled externally and depends on the properties of the stimuli. Selectivity changes as new skills and knowledge emerge in development. Ruff and Rothbart (1996) suggest using the individual's actions as a guide for identifying whether attention is voluntary or involuntary. They assume that individuals are voluntarily controlling their attention if they can direct, maintain, and shift their focus according to the directions of another person.

The emergence of voluntary control of attention occurring during the infant's first year coincides with the development of three related, but anatomically distinct, attentional systems. The first attentional system of importance is the reticular activating system, which ascends from the brain stem to the cortex and is thought to be involved in maintaining and adjusting general alertness. It is believed that this system focuses attention on important aspects of the environment and prevents distraction, thus facilitating defensive behavior (Derryberry & Rothbart, 1997). The second attentional system that matures during the end of the first year of life is the posterior attentional system. Neurologically, this system is distributed across the brain's superior colliculus, the pulvinar nucleus of the thalamus, and the parietal lobe within the cortex. The operations of this system allow attention to move from one location to another through the engagement and disengagement of attention. In addition, this system allows for the adjustment of the breadth of attention to closely focus on details or give a broader, more general picture of the information (Posner & Rothbart, 1992). The third system, which develops later than the other attentional systems, is the anterior attentional system, which is proposed to be the most important to the development of effortful control. This system is located within the frontal cortex and is viewed as an executive system that regulates sensory information (Rothbart, Derryberry, & Posner, 1994). Furthermore, Posner and Rothbart (1992) suggest that this system underlies the conscious, willful control of behavior through which the individual can regulate more reactive motivational functions. Although aspects of effortful control can be seen at the end of the first year, this system

is relatively late to develop, the most rapid maturation occurring during toddlerhood (Derryberry & Rothbart, 1997). It should be noted that there is debate as to the fundamental competencies underlying the development of executive function skills (Zelazo & Reznick, 1991; Zelazo, Reznick, & Pinon, 1995). A number of researchers suggested that increases in working memory (another "frontal" function) may account for the development of these skills (Zelazo et al., 1995), whereas others argued for the importance of an inhibitory component toward understanding executive control (e.g., Diamond, 1991).

By the end of the first year of life, infants are capable of controlling their visual attention in such a way that reactivity to exogenous stimuli is influenced. Reactivity is initiated when the infant looks toward an object. However, several successive changes may take place that affect reactivity. First, reactivity is augmented when the infant looks intensely at the object. Second, it is maintained when the infant continues to look at the object and is reduced when the infant averts his or her gaze. Third, it is terminated when the infant looks away from the object (Rothbart & Derryberry, 1981). The development of the three attentional systems provides the young child with the neurophysiology necessary to regulate reactivity. However, not all children will be able to engage in these behaviors successfully to control reactivity. There are clear individual differences in the ability to utilize attention to successfully control emotion and behavior. For example, Rothbart (1981, 1986) found dramatic increases in positive affect and decreases in distress from 3 to 6 months during episodes of focused attention. Moreover, negative affectivity is believed to interfere with the child's ability to explore and learn about the environment (Ruff & Rothbart, 1996).

Regulation at the emotional level

Emotion regulation refers to efforts on the part of the individual to manage, modulate, inhibit and enhance emotions (Cicchetti et al., 1991; Kopp, 1982, 1989; Thompson, 1994). For example, the use of strategies such as self-comforting, help seeking, and distraction may assist the child in managing early frustration and fear responses. Approach behaviors and gaze aversion may assist in the modulation of joy and pleasure. These kinds of behavioral strategies begin to develop early in the first year of life and affect the both the continued development of regulation and subsequent social skills and behavior.

Recent research on the regulation of types of negative affect suggests processes through which this regulation affects behavioral control later in development. Stifter and Braungart (1995) examined changes in the types of regulatory behaviors that infants use to manage emotional reactivity and observed that there were relations between these behaviors and changes in negative affect. Stifter also found that emotional regulation in response to frustration in infancy was related to compliance in toddlerhood (Stifter et al., 1999). Grolnick and colleagues (Grolnick, Bridges, & Connell, 1996) described the relations between emotion regulation strategies and distress among a sample of 2-year-olds observed in a delay of gratification paradigm and a separation situation. They observed that the strategy of visual reorienting during these tasks was the most commonly used form of emotion regulation and the one that was most predictive of decreases in distress. Eisenberg and colleagues (1993, 1994, 1995) found relations among emotionality, emotion regulation, and peer competence in early childhood. Rothbart and colleagues (Rothbart et al., 1990) observed that at least one specific emotion regulation behavior, that of attentional control, is related to decreases in negative emotionality in infancy. Buss and Goldsmith (1998) and Diener and colleagues (Diener, Manglesdorf, McHale, & Frosch, in press) also observed that a number of different behaviors that infants display when observed in frustrating or constraining situations appear to reduce negative affect. Taken together, these studies demonstrate that there are individual differences in the use of particular emotion regulation behaviors, that some behaviors are more effective than others for reducing negative affect, that the use of particular emotion regulation behaviors changes over time, and that certain

behaviors affect the development of social competence.

Recent research suggests that failure to acquire the skills needed to manage emotional responses and emotional arousal may lead to difficulties in social interaction (Calkins, 1994; Cicchetti, Ackerman, & Izard, 1995; Eisenberg et al., 1993, 1994; Rubin et al., 1995). Fabes and Eisenberg (1992) hypothesized that reactivity and regulation exert an effect on social behavior by interacting with one another. Such a hypothesis has been proposed to account for both socially withdrawn and aggressive behavior with peers (Eisenberg et al., 1993, 1994; Fox & Calkins, 1993; Rubin et al., 1995). For example, Fox and Calkins (1993) argue that the influence of a child's characteristic emotional arousal or reactivity on social behavior will depend on the extent to which the child engages in behaviors that enable him or her to manage emotional reactivity in a constructive manner. In addition, children who experience extreme arousal or emotional reactivity may have difficulty regulating those experiences, regardless of the strategies they may attempt to use.

Eisenberg and colleagues have investigated these issues with school-age children (Eisenberg et al., 1993, 1994; Fabes & Eisenberg, 1992) and found that individuals who are highly emotional in response to anger-inducing events and poor at regulation are likely to display aggression in social situations. Eisenberg hypothesized that this relation is observed because the experience of intense anger results in a loss of behavioral control. Strategies such as attentional control (focusing on an object other than that which may be arousing), avoidance (turning away from an arousing stimulus), and instrumental coping (working with the situation) may be useful in dealing with anger (Eisenberg et al., 1993, 1994). Children who fail to use such strategies tend to vent their emotions and may become aggressive. Both the tendency to display modulated affect and the ability to utilize appropriate affect regulation skills enhances the development of social skills (Rubin et al., 1995).

It is important to study the relations between reactivity and regulation in specific contexts. Their interaction in producing either adaptive or maladaptive social behavior may be a function of the context in which they are measured. So, for example, Henderson, Fox, and Rubin (2001) found that socially withdrawn school age children were no different on measures of executive function than nonwithdrawn age mates when they were tested individually. However, when measures of executive attention were assessed within a social situation, these same socially withdrawn children performed less well compared to their nonwithdrawn counterparts.

In sum, recent research on infant and childhood development suggests that there are important regulatory developments that occur on multiple levels, these developments are likely to be hierarchically organized, and basic physiological processes contribute to early developments in attention and emotional functioning. Individual differences in these processes are likely to be implicated in both personality and behavioral adjustment during the early childhood years, when the self-regulation of emotion and behavior become core indices of successful adaptation.

Early Childhood Self-Regulation and Its Relation to Social Withdrawal and Aggression

Over the last decade, we conducted longitudinal research on the origins of early childhood personality and behavior problems. We applied a multilevel conceptualization and a multimethod empirical approach to try to understand the etiology of, and pathways to, childhood social withdrawal and aggression. Our assessments include physiological measures; parent report of temperament and behavior problems; and laboratory assessments of emotion, attention, caregiver behavior, and child social behavior. Findings that support the notion that deficits in self-regulatory functioning at several levels underlie these behavior problems are presented.

Inhibition and childhood social withdrawal

For the last several years, we followed three longitudinal cohorts of children across the in-

fancy and childhood period and observing the emergence of behavioral inhibition and its associations to childhood social withdrawal. Behavioral inhibition refers to the child's initial response to novel events or unfamiliar adults. As first described by Kagan and colleagues (Garcia–Coll, Kagan, & Reznick, 1984; Kagan & Snidman, 1991), young children who are behaviorally inhibited display low approach behavior, become, and remain, vigilant for the duration of exposure to the novel object; and often seek the proximity of a caregiver. Social withdrawal refers to the child's social response to unfamiliar peers (Coplan, Rubin, Fox, Calkins, & Stewart, 1994). Children who exhibit social withdrawal when confronted with unfamiliar peers do not engage in social interaction, nor do they initiate or respond with social behaviors to social bids from unfamiliar peers. Our focus in this work was on the description, etiology, and outcomes of these early behavioral tendencies. In this research, our measures of physiology include brain electrical activity, cardiac activity, and cortisol. Of primary interest, though, is the role that individual differences in the pattern of frontal EEG activation play in the development of maladaptive social behavior in the preschool years. Our working hypothesis was that the pattern of frontal activation reflects the child's underlying motivational disposition to either approach or withdraw from novelty or social challenge. This hypothesis is based on a wide variety of data implicating the two frontal regions as being differentially involved in the tendency to express affects associated with either approach or withdrawal (Fox, Calkins, Porges, Rubin, Coplan, Stewart, Marshall, & Long, 1995). In a recent study, infants were screened in their homes at 4 months of age using a battery of visual, auditory, and olfactory stimuli designed to elicit negative affect, positive affect, and motor activity (Kagan, 1997b; Kagan & Snidman, 1991). This screening procedure was designed to select infants who would display inhibited behavior and negative affect at later ages. In the initial study (Calkins et al., 1996) a sample of 200 infants was seen at 4 months; a subsample of 81 infants was selected for follow-up visits at 9 and 14 months. At 9 months, EEG data was collected during a baseline procedure, and at 14 months, infant behavior was observed in a series of episodes designed to elicit inhibited versus uninhibited behavior.

The infants who were selected for the follow-up study were clustered into three groups: infants high on motor activity and negative affect and low on positive affect, infants high on motor activity and positive affect and low on negative affect, and infants who are low on all dimensions. The data from this study reveal that these behavioral tendencies are accompanied by specific patterns of brain electrical activity. Infants who were selected at 4 months because they displayed high amounts of negative affect and motor activity exhibited greater relative right frontal activation at 9 months. Infants who displayed high amounts of positive affect and motor activity at 4 months exhibited greater relative left frontal activation (Calkins et al., 1996). Infants low on the three dimensions fell in the middle of the two extreme groups on the measures of frontal activation. A subsequent follow-up of these infants found that the pattern of reactivity and their 9-month frontal EEG activity combined were significant predictors of social withdrawal at age 4 years. Highly reactive and negative infants who displayed right frontal EEG asymmetry at 9 months of age were more likely to exhibit social withdrawal at 4 years of age, compared to similarly reactive infants exhibiting left frontal EEG asymmetry (Henderson et al., 2001). These findings are consistent with findings from the adult literature that demonstrate that adults with resting right frontal asymmetry are more likely to rate video film clips with negative affect compared to adults with left frontal asymmetry (Tomarken, Davidson, & Henriques, 1990). Differences in frontal asymmetry may reflect the fact that the left and right hemispheres are differentially specialized for the expression of emotions associated with either approach or withdrawal (Fox, 1991).

To what degree are these early asymmetry differences stable, and what behavioral consequences are associated with stability? Fox and colleagues (Fox, Calkins, & Bell, 1994) ex-

amined this issue and concluded that asymmetry is modestly stable over time and related in important ways to behavioral outcomes. In the follow-up of their selected sample at 24 months of age, they observed that children who maintained a pattern of right frontal asymmetry over the first 2 years of life were more likely to be inhibited, compliant, less impulsive, and high on a measure of frustration tolerance. In a more extensive follow-up, Fox and colleagues (2001) report on the degree of continuity and discontinuity of behavioral inhibition to social withdrawal from among a sample of infants selected for temperamental negative reactivity. They find that approximately 25% of these infants (already an extreme groups sample based on their selection for temperamental reactivity) exhibited continuous behavioral inhibition and social withdrawal. The other 75% either showed no clear pattern or appeared to display moderation in their responses to social challenge. An examination of the EEG data for children who remained socially withdrawn versus those who changed revealed that among the former group, the children continued to exhibit right frontal EEG asymmetry whereas among those whose phenotypic expression of behavior changed, there was a corresponding change in the pattern of frontal EEG asymmetry. Fox and colleagues speculated on the role of the caregiving environment in moderating change in temperamental reactivity and providing the child with the regulatory skills necessary to engage in adaptive social behavior (Calkins, 1994; Fox et al., 1994). In recent work by Rubin and colleagues, there are hints as to the dimensions of caregiving that may be important in such continuities and discontinuities. For example, Rubin recently observed that children who remain consistently inhibited over the course of the toddler period were temperamentally fearful in infancy, highly distressed when separated from the mother, and likely to have oversolicitous mothers (Rubin, Hastings, Stewart, Henderson, & Chen, 1997). Rubin, Cheah, and Fox (2001) similarly found that for certain contexts (free play in particular) mothers exhibiting overintrusive and oversolicitous behaviors were more likely to have continuously withdrawn children.

Infant emotional reactivity has important implications for the development of regulatory mechanisms that will assist the child in a variety of social settings. The extension of these findings is that patterns of physiology and behavior that are identifiable in early infancy play a role in the development of adaptive versus maladaptive behavior in early childhood. This hypothesis was investigated when two cohorts of children from both selected and unselected longitudinal samples were assessed in the laboratory at age 4 (Fox et al., 1996). At this assessment, both cohorts of children participated in a physiological assessment and a play assessment with three unfamiliar peers, and parents assessed the child's level of problem behavior (internalizing versus externalizing) using the Child Behavior Checklist (CBCL). The data indicated that children who displayed a physiological profile of greater relative right frontal EEG asymmetry and socially withdrawn behavior with peers were more likely to be rated by mothers as high on internalizing behaviors than children who were socially withdrawn with peers but displayed a pattern of greater relative left frontal asymmetry. In addition, children who displayed a pattern of right frontal EEG asymmetry and who were social with peers, rather than withdrawn, were more likely to be rated by mothers as high on externalizing behaviors (Fox et al., 1996) in comparison to social children, who displayed a pattern of left frontal asymmetry. These data demonstrate that the pattern of frontal EEG asymmetry and the behavioral profile with peers was predictive of different patterns of maladaptive behaviors as rated by mothers.

Patterns of frontal EEG asymmetry appear to reflect early motivational dispositions to approach versus withdrawal (Fox, 1991, 1994; Fox et al., 1996). In addition and more generally, the prefrontal cortex and its multiple areas or regions underlies competencies associated with verbal mediation, analytic abilities, monitoring, and inhibition of prepotent responses, all of which may be directly tied to emerging emotion regulation skills (Dawson,

Hessl, & Frey, 1994; Fox et al., 1996). Emotional control is thus a consequence of the dynamic interaction of the frontal regions (Fox, 1994). Again, however, there is good evidence that interactions with caregivers also provide children with opportunities for acquiring affect regulation skills (Calkins & Johnson, 1998; Cassidy, 1994; Thompson, 1994). Further, as a number of researchers observed, there is clear evidence that these emotion regulatory skills and abilities have implications for the development of appropriate versus inappropriate social behaviors (Cole, Michel, & O'Donnell, 1994; Eisenberg et al., 1995, 1996; Rubin et al., 1995; Schmidt & Fox, 1998). In their model of temperament, Rothbart and Posner (1985) views the development of prefrontal skills involved in regulation as a critical element. There are clear individual differences in the maturation of these skills; moreover, the development of these skills may be a function of the history of caregiver–infant interaction. The next phase of research in this area should attempt to identify how caregiving behaviors and context influence the development of these executive skills that are so important for self-regulation.

Anger and childhood aggression

In recent research (Calkins & Dedmon, 2000; Calkins, Gill, & Williford, 1999; Smith, Lomax, & Calkins, 1998), we also applied many of the principles of developmental psychophysiology and psychopathology to the study of early emerging externalizing problems. In two longitudinal studies, we investigated the self-regulatory components of early social behavior by focusing on children with early appearing problems managing frustration and aggressive behavior. In one study, for example, used two separate administrations of the CBCL for 2- to 3-year-olds (CBCL-2/3) to recruit 50, 2-year-old children with stable externalizing behavior problems (aggression/destruction) in the borderline clinical range (labeled "high risk") and 50 children without such problems (labeled "low risk"). The children were matched on age, socioeconomic status, gender, and race. We assessed these children in the laboratory in a series of procedures (emotion tasks, attention tasks, delay of gratification, and compliance tasks) designed to elicit regulation across multiple levels. Our physiological measures were resting and response measures of HR and RSA. Previous research with inhibited infants and children suggests that regulatory efforts may be partly a consequence of parasympathetic nervous system functioning (Porges, 1996; Stifter & Fox, 1990) as well as frontal brain activity. In addition, we examined maternal behaviors in the laboratory in a different set of tasks. Finally, in a second assessment we observed the children in a peer play situation and examined the degree to which the aggressive children displayed socially appropriate versus inappropriate behavior.

The findings from this study provided preliminary support for the idea that early developments in self-regulation support early adjustment and failures of self-regulation may be implicated in the display of acting-out, or externalizing, behavior problems. First, we observed that high risk 2-year-olds did not display the same pattern of vagal suppression as low risk children when challenged behaviorally and emotionally. Indeed, across all the challenging situations with which they were presented, aggressive children showed only modest decreases in RSA from baseline to challenge, unlike their control counterparts, who consistently displayed significant decreases. The behavior of the children mapped onto their physiological response as well. Aggressive children spent less time attending to the task and more time fretting or throwing tantrums, and they engaged in fewer putative regulatory behaviors than did the control children. These children also had difficulty complying with maternal requests and displayed significantly more defiance (Calkins & Dedmon, 2000).

In our second assessment of these children at age 2, we found that children characterized as aggressive by parents were, in fact, more aggressive in play with an unfamiliar peer, even when the mothers of the children were present in the room. Moreover, the aggressive behavior became more frequent over the

course of the play session. Thus, these children had difficulty controlling aggressive impulses under conditions of novelty and when their behavior is being closely monitored (Calkins et al., 1999). In sum, there is good evidence from this study that these children displayed deficits in regulation across several levels of functioning—physiological, emotional, attentional, behavioral, and social (Calkins & Dedmon, 2000; Calkins et al., 1999). We conducted follow-up assessments of these children at ages 4 and 5, and our preliminary data suggest that there is a high degree of stability of these problems and, indeed, good evidence that early regulatory deficits are linked to Attention Deficit Hyperactivity disorder (ADHD). The correlation between CBCL externalizing behavior at ages 2 and 4 was $r = .67$, $p < .0001$, and the percentage of children in the high risk category who received a clinical diagnosis of ADHD at age 4.5 was 40 versus 10% for the control children (Gerrard, Anastopoulos, Calkins, & Shelton, 2000).

These data provide some evidence, then, that regulatory deficits are implicated in early externalizing-type behavior problems, but they do not necessarily provide support for a developmental model of self-regulatory contributors to behavior problems. Given that the self-regulation data were collected contemporaneously, we do not know whether they are a cause or merely a symptom of early behavior problems.

To address the role of very early developing self-regulation and the emergence of behavior problems, we are conducting a second longitudinal study in which we selected infants that might be predisposed to difficulty with aggression because of a susceptibility to be easily angered. Toward this end, we screened a cohort of 360, 6-month-olds infants using a battery adapted from Goldsmith's Laboratory Temperament Assessment Battery assessment of anger (Goldsmith & Rothbart, 1993). We selected infants who scored above the 50th percentile on the anger measure from the laboratory assessment and above the 50th percentile on the anger scale from the Infant Behavior Questionnaire, a maternal report measure of infant temperament. Of the larger sample, 77 infants met the criteria for the "low frustration" group and 85 met the criteria for the "high frustration" group. Preliminary analyses revealed that there was no relation between frustration group and sex of child (47 of the 85 infants in the high frustration group were females, compared with 36 of the 77 infants in the low frustration group), marital status, or child birth order.

To examine the regulatory functioning of these infants, we observed them in a battery of emotion and attention tasks while collecting cardiac data. Our analysis of their regulatory functioning revealed that easily frustrated infants displayed less physiological regulation during a sustained attention task, had difficulty sustaining attention, and engaged in different sorts of regulatory behaviors during emotion-eliciting situations. They engaged in less visual distraction and more tantrums than did less easily frustrated infants (Calkins, Dedmon, Gill, Lomax, & Johnson, in press). We propose that these infants displayed potentially problematic self-regulatory functioning very early in development. Important to their developmental outcome is the extent to which they receive environmental support that may assist them in acquiring the regulatory skills that seem to be lacking due to their excessive temperamental reactivity. Note the similarity in theme to issues raised with respect to social withdrawal. In that instance, as here, developmental outcome is a function not only of initial temperamental reactivity and maturation of self-regulation but also of the extent to which the environment (caregivers and context) does or does not support the development of adaptive behaviors in the service of self-regulation.

In prior work, we found significant links between environmental support (parenting behaviors) and child regulation at the levels of physiological, emotional, and behavioral regulation (Calkins, Smith, Gill, & Johnson, 1998). Toddlers of mothers who used more positive, reinforcing, and guiding behaviors were more physiologically well regulated, engaged in more constructive emotion regulation behaviors, and were more compliant in adult-directed contexts than were toddlers of mothers who were more controlling and nega-

tive. Our expectation with our infant sample is that, with sensitive and contingent caregiving, these regulatory achievements will not be compromised in the long term.

Our analysis of maternal behavior, however, suggests that the reciprocal processes that take place between infant and caregiver may be more challenging for these frustrated infants. We found that, across several different types of mother–infant interactions, mothers of frustrated infants were significantly more intrusive and less sensitive than were mothers of nonfrustrated infants. However, it was also the case that the frustrated infants displayed more negative affect, even in these low-stress interactions. Once this negative affect was controlled for statistically, the differences between the two groups of mothers no longer existed (Calkins, Dedmon, & Hungerford, 2002). These findings suggest that the day to day interactions between mother and infant were driven, at least to some extent, by the infant's frustrated temperament. Again, however, the long-term implications of such a dynamic are unclear.

Our longitudinal studies of early personality provide support for the proposition that multiple levels of self-regulation are implicated in early personality development and the emergence of some types of behavioral problems. However, our attempts to integrate data collected across multiple domains of functioning create a number of unresolved questions and challenges.

Challenges to the Study of Multiple Levels of Self-Regulation

A multiple levels approach to the study of early personality and behavioral adjustment faces both conceptual and empirical challenges. First, methodologically, the study of psychophysiology and physiological regulation is confronted with numerous difficulties. These include the synchronization of physiology and behavior, the stability of physiological measures across time, and the convergence of behavior and physiology. These issues are discussed in detail elsewhere (Fox et al., 2000; Fox & Calkins, 1999). Nevertheless, they continue to complicate our understanding of psychophysiological data. Second, we argue theoretically for a reciprocal child–environment interactional process that builds the regulatory system over the course of infancy and childhood. However, we have failed to specify how this might happen and what the likely origins of early individual difference might be. Third, empirically, the study of multiple levels is challenged by the developmental process itself: how do changes in one regulatory system affect changes in another system and how does one measure such reciprocity? In this section, we discuss some of these problems in detail and suggest directions for future research.

Methodological challenges to the study of physiological regulation

Although the number of research laboratories investigating links between physiological and psychological phenomena has grown, a number of overlooked technical issues remain that are relevant to these studies and to the research on physiological measurement in general. Perhaps the most important one is the issue of the time course of change of each of these systems. It is clear from the physiological literature that each of the various autonomic responses has quite a different time course, ranging from milliseconds to seconds and in some cases minutes, before a change in the response can be measured. The fact that each of these systems elicits a different time course of change would seem problematical to the different approaches for the study of emotion. For example, if physiological measurement is to describe patterns of arousal, then the choice of measure will obviously influence the conclusion as to whether the subject has indeed become aroused due to the emotional stimulus. Changes in cortisol are only noted some 20–30 min after the eliciting event. If cortisol is measured during an emotion, one would not conclude that the subject was aroused during that emotion. Similarly, if one is measuring patterns of physiological change during the expression of discrete emotions, the time course for these changes may preclude finding these patterns if ecologically valid expressive responses are utilized. Ek-

man and colleagues, for example, used a task in which subjects held the facial musculature changes associated with certain emotions (the directed facial action task) for long periods of time for just this reason (e.g., Ekman, Levenson, & Freisen, 1983).

The differing time course of physiological systems may also be helpful in understanding certain aspects of emotional experience. Fox (1991) suggested that the slower changing autonomic responses that are associated with the expression of certain discrete emotions may be more related to the intensive aspects of the experience than to the central feeling state. Certain emotions may be intensified by the contribution of changing autonomic and visceral tone. Certain emotional states, which last over prolonged periods of time, may do so because of the slow changing physiological systems that are involved in the expression of the emotion. Of course, the degree to which these states last may be a function of individual differences in physiological lability. To the best of our knowledge, these issues are not thoroughly explored in the literature, although the time course of these systems is well defined.

A parallel issue in the use of multiple physiological measures is the degree to which we understand the relations among different physiological systems. There are a number of levels on which this problem may be approached. Perhaps the most simple and direct one would be to record multiple measures and examine simple bivariate correlations among them. If, in response to or during an emotion one system goes up, does the other system go up or down? Patterning of this nature among systems that share some similarity (e.g., among autonomic measures) has had a long history in psychophysiology. Classical approaches that emphasized the role of arousal maintained that there should be a correspondence among physiological systems in their response to emotional stimuli. Physiological arousal should, it was argued, be reflected in multiple measures. These responses should all go up or down together. However, researchers were quick to discover that this was not the case. Indeed, Lacey and Lacey (1970) revealed that there were different directional patterns to autonomic measures in response to a stressor. The concept of a unitary notion of arousal as measured by multiple systems could not be supported.

Perhaps a more informative strategy would be to understand the particular physiological systems that are being tapped and the consequent underlying physiology and anatomy of those systems, so that particular patterns of relationship among measures can be interpreted with greater depth and understanding. As an example, consider the research on blood pressure and HR. There is a large body of work that attempts to understand the physiological mechanisms that relate these two systems in order to understand both the unique nature of each and the manner in which these two systems overlap. The unique feedback systems between blood pressure and HR via baroreceptor mechanisms allowed scientists to understand how blood pressure and HR covary. The use of the measures together can illuminate issues regarding the nature of interaction among these physiological systems rather than simply among an emotion and a single autonomic index.

A second issue in the study of multiple response measures of emotion involves the nature of emotion behavior/physiology synchronization. As discussed above, different physiological systems have differing time courses. Measuring more than one system involves understanding the manner in which these different time courses overlap and interact. But what should we make of measurement of the emotion itself? What is its time course and how does it factor into the pattern that is being described? Again the history of and answer to this question are long and complex. There are many definitions of emotion, and there were multiple attempts at measurement of emotion. Ekman (1984) presents one theoretical position that may be helpful in studying emotion–physiology relationships. Emotion, in Ekman's conceptualization, is a fast occurring event linked directly to changes in facial expression and autonomic activity. The time course of emotion may be viewed as on the order of seconds. Feeling states that occur over longer periods of time are thought of as mood states rather than emotions. If one

accepts these definitional distinctions, one can begin to find ways to link physiology to emotion behavior. For example, we utilized facial expression as an anchor in determining the presence of specific central nervous system states in infants. In our studies of brain electrical activity and its relation to emotion, we synchronized changes in the ongoing EEG to changes in facial expression (Fox & Davidson, 1987). This was possible because the resolution and time course of the EEG is on the order of milliseconds as is the resolution and time course of facial expressive change. Because their time changes are compatible, it is not unreasonable to link the two.

But can we link expressive changes to autonomic activity? Again, because most autonomic change is on the order of seconds, it is difficult to find instances of expressive change that match this temporal level. Ekman (1984) developed the directed facial action task for just this purpose. In this task, a subject is required to move his or her facial muscles into a pattern resembling a discrete emotion. The subject must then hold that expression for a long period of time, so that changes in autonomic activity may be recorded. Although such a pattern is interesting in the abstract and can inform us about the relations among certain behaviors and physiology, its direct relation to ecologically valid changes in facial activity is dubious. Seldom are facial expressions of discrete emotion in "real life" held for such long periods of time. It is therefore difficult, if not impossible, in ecologically valid situations to synchronize emotion and autonomic behavior—if emotion is solely defined by the presence of specific facial behaviors.

One could define emotion by the stimulus condition itself. However, the obvious drawback here is that individuals may respond quite differently to the same condition and, if physiology and behavior are linked, one may not find clear relations when differing emotions are elicited across individuals. For example, we recorded physiology in young infants in response to maternal separation (Fox, Bell, & Jones, 1992). Not all infants cry in response to separation or are distressed. Indeed, we found that the physiology of infants who are distressed is quite different from those who are not upset in response to this identical stimulus situation. Collapsing data across individual subjects would obscure these differences. As an alternative to either collapsing data across individuals or anchoring emotion to facial expression, which is a fast changing response, one could use other response measures of emotion. For example, in the case of infant response to maternal separation, we grouped infants into those who cry versus those who do not cry in response to this event (e.g., Davidson & Fox, 1989). Interestingly, the discrete facial expression does not discriminate physiological activity within individual infants who cry in response to separation. We found, for example, that some infants cry and exhibit anger expressions whereas others cry and exhibit distress or sadness. Physiologically (at least with regard to the EEG measures we utilized), these two subgroups do not differ. Thus, the use of vocal measures of emotion proved to be more successful in parsing emotion behavior and physiology than facial expressions of emotion.

Origins of individual differences in regulation

Researchers have begun describing regulatory processes and their effects on development, and one important issue that they address concerns the etiology of these processes. Two very different views of these origins are offered. One theoretical perspective emphasizes the caregiver–child relationship as the primary context in which children learn to regulate their emotions, for example. This perspective typically emphasizes particular maternal behaviors as more or less supportive of adaptive emotional development in the child. Literature on face to face interactions between mothers and infants focuses on the experience of mutual regulation within the dyad as important in infants' emotional development (Gianino & Tronick, 1988; Tronick, 1989; Tronick, Cohn, & Shea, 1986). Tronick (1989) argued that positive emotional development may be associated with an experience of coordinated interactions with a caregiver.

In the literature on face to face play, maternal contingent responsivity to infant interactive behavior was found to relate to infant behaviors presumed to reflect arousal regulation, such as decreased gaze aversion and negative affect and increased smiling (Fogel, Diamond, Langhorst, & Demos, 1982; Gusella, Muir, & Tronick, 1988; Symons & Moran, 1987).

Researchers also draw on attachment theory to propose that maternal sensitivity and subsequent child attachment strategies play a formative role in emotion regulation development (Cassidy, 1994; Gunnar, 1998; Sroufe, 1996). Theorists who emphasize the role of early experiences with caregivers for the development of emotion regulation often focus on the interpersonal experiences that are most relevant to the infancy period. Much research in this area is grounded in Ainsworth's (1969; Ainsworth, Blehar, Waters, & Wall, 1978) and Bowlby's (1969) theory of attachment. The flexibility that a well-regulated child needs to express a range of emotions is proposed to develop, at least partially, through a history with a caregiver who responds sensitively much of the time to a range of infant emotional signals without selectively ignoring any. There is, however, limited data demonstrating such relations. In one study, inhibited toddlers with secure attachment relationships displayed lower stress reactivity, as measured in salivary cortisol, than did inhibited toddlers with insecure attachments (Nachmias, Gunnar, Manglesdorf, Parritz, & Buss, 1996), suggesting that some characteristics of the secure relationship provide the child with the ability to cope with stressful situations and events.

A different theoretical perspective suggests that individual differences in observable emotion regulation are based on individual differences in underlying physiological functioning (Calkins et al., 1996; Fox, 1989; Porges, 1997). It is clear that physiological developments that occur during the first years of life are critical for developments in self-regulation (Posner & Rothbart, 2000; Thompson, 1994). Researchers identified important physiological correlates of emotion regulation strategies and behaviors (Calkins & Dedmon, 2000) and also found that particular physiological patterns predict later regulation (Fox et al., 1995, 1996; Porges, Doussard–Roosevelt, & Maiti, 1994).

Although it may appear that these two points of view (individual differences in regulation as a consequence of endogenous vs. exogenous differences) are not integrated, this is not the case. Several researchers suggest that internal factors, such as the child's physiological reactivity, and external factors, such as experiences with early caregivers, both make important contributions to the development of emotion regulation (Calkins, 1994; Calkins & Johnson, 1998; Calkins et al., 1998; Cicchetti et al., 1991; Gunnar, 1998). Despite the acknowledgment that internal and external factors probably interact, relatively little empirical work with human infants and children investigated the interface between biologically based and relationship-based processes by which emotion regulation develops.

One hypothesis that we advanced that is based on the psychophysiological work is that child characteristics may place limits on the development of self-regulation such that particular achievements are compromised or particular adaptive strategies are less likely to be used than others. These constraints may operate directly on self-regulation or through their effects on parenting. Thus, for example, a child's characteristic level of physiological arousal may directly affect how and when the mastery of states of arousal develops in early infancy (Porges et al., 1994). Similarly, behavioral tendencies, such as extreme fear or frustration, may influence the development of emotion regulation in late infancy and toddlerhood (Braungart–Rieker & Stifter, 1996; Fox & Calkins, 1993). Alternately, the child's gender may affect the kind of strategies the parent uses for discipline during toddlerhood (Keenan & Shaw, 1997). Finally, the child's intellectual abilities may limit how able he or she is to take advantage of environmental input and learn self-regulation. In short, characteristics of the child that are present from birth may place limits on both the direct and indirect acquisition of self-regulation and must, by extension, be incorporated into a theory of how regulatory developments and deficits influence child adjustment (Calkins, 1994; Calkins & Dedmon, 2000).

Again, though, the problem is how to integrate this point of view with the notion that the caregiving environment will play a role as well. One strategy that has been used is to assess physiological functioning in infants exposed to deviant or less than optimal kinds of parenting. Thus, for example, Jones and colleagues found that infants of withdrawn mothers had significantly lower levels of norepinephrine, epinephrine, and dopamine than infants of intrusive mothers (Jones, Field, Fox, Davalos, Malphurs, Carraway, Schanberg, & Kuhn, 1997). Alternatively, manipulations of social stimuli were also conducted to examine the effects on child functioning. Bazhenova and Porges (1997) observed that 5-month-old infants demonstrated decreases in RSA and in positive affect when exposed to a standard still-face procedure with the experimenter. The reverse pattern was observed in a subsequent social interaction. Finally, Calkins found that maternal negative control with toddlers was significantly related to lower vagal suppression (poorer regulation) during a positive emotion task (Calkins et al., 1998). More research of this kind is needed to understand the magnitude and direction of effects of the caregiving environment.

Other studies examined relationships between traditional attachment constructs and infant physiological functioning and found results that further support the suggestion that early, sensitive maternal behavior may impact developing infant physiology. Donovan and Leavitt (1985) found interesting differences between the cardiac responses and overt behavior of insecurely attached infants, who presumably had less sensitive mothering. Gunnar, Brodersen, Nachmias, Buss, and Rigatuso (1996) studied infant cortisol responses in relation to maternal responsivity and infant attachment classifications. Their work indicates that high fearfulness in 2-year-olds was associated with higher cortisol responses to inoculations only for infants in insecure relationships with their accompanying parent. Furthermore, earlier data taken when the infants were 2, 4, and 6 months old revealed that attachment security at 18 months was related to greater maternal responsiveness and lower cortisol baselines. Corroborating these findings was a study that found that securely attached 18-month-olds who were fearful during a novel laboratory event did not exhibit an elevation of cortisol, unlike their wary counterparts in insecure relationships (Nachmias et al., 1996).

Thus, there is a growing literature that integrates the study of developing physiological regulation with assessments of the influence of the environment. Nevertheless, a comprehensive study of these relations over time is lacking. Presumably, as more longitudinal work is conducted, these relations will be more fully illuminated.

The development and reciprocity of multiple systems of self-regulation

Although there are some clearly identifiable development progressions that have been identified at the physiological, attentional, emotional, and social regulatory levels, there has been less emphasis on how developments in each of these levels affect one another. Thus, for example, while much is known about the changes in brain electrical activity that can be observed across the infancy and childhood periods, less work has been conducted linking these changes to specific changes in other types of regulation. Moreover, the direction of effects of individual differences in specific levels of regulation on other levels of regulation is another largely unexplored area. What we know currently about the relations among levels of regulation, we know at the molar level. Future investigations must be aimed at the more micro level: How do individual differences in particular types of physiological regulation affect the development of specific emotion regulatory processes that are implicated in the development of aggression and childhood social withdrawal? These process-oriented questions are likely to be more informative than the correlational kinds of findings that we have relied on to understand these early outcomes.

Summary and Conclusions

Many researchers who study change from a developmental psychopathology perspective

articulate a view of social development that proposes that development will proceed on multiple, reciprocally interacting levels. In our view, these levels can be usefully studied by focusing on self-regulatory functioning. Theories of early self-regulation assume that infants display individual differences in behavioral reactivity and regulation that have implications for subsequent development. These behavioral differences were also linked to physiological differences observable in the HR, cortisol response, and brain electrical activity. Moreover, these behavioral and physiological differences are also linked to environmental events and stimulation. In applying such a view to our studies of childhood social withdrawal and aggression, we observed physiological correlates of these behavior problems, as well as behavioral manifestations of the failures of self-regulation that lead to such problems. We acknowledge that there are a number of challenges to this work that must be addressed, including a more focused effort to understand the multiple pathways and complex interactions that exist between child and environment and a better understanding of how developments at different levels of the self-regulatory system affect one another over time. Nevertheless, we are convinced that a complete understanding of early childhood functioning is dependent on research that focuses on the differentiation and integration of the various components of the self-regulatory system across the first few years of life.

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